INTERNATIONAL PERSPECTIVES ON COASTAL OCEAN SPACE UTILIZATION

USC Sea Grant
UNIVERSITY OF SOUTHERN CALIFORNIA

Phyllis M. Grifman
James A. Fawcett
EDITORS

INTERNATIONAL PERSPECTIVES ON COASTAL OCEAN SPACE UTILIZATION

Proceedings from the Second International Symposium on Coastal Ocean Space Utilization (COSU II) held April 2-4, 1991, Long Beach, California

Edited by

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and
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University of Southern California

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International Perspectives on Coastal Ocean Space Utilization
Proceedings of the Second International Symposium on
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James A. Fawcett

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Technical Papers on Waves and the Design of Coastal Structures

* *Not formally presented at COSU II. Submitted for publication only.*

Editor's Preface

Compiling and editing the essays in this volume was a challenging and daunting task. The fifty-seven papers submitted for publication arrived in a variety of styles and media (computer diskettes, typewritten copy, photocopies, even FAXes), and had to be converted or retyped before they could by typeset.

We have tried to craft this volume into a cohesive and readable whole. All of the papers were edited for sentence clarity, style and consistency. Those texts that were more than superficially touched by the senior editor are noted following the text: *(Edited by P. M. Grifman)*. In those cases, she takes full responsibility for any omissions or errors that may have crept into the text due to language difficulties.

Much of the artwork and graphics had to be manipulated or redrawn to fit the book's format, and, in a few cases, art that was too poor in quality for reproduction had to be eliminated. We would like to thank Michelle Bradley and Kevin Bell of USC Sea Grant for their work in redrawing and formatting graphics that could not otherwise have been included.

We have taken some liberties with the style of references used. All citations appear in the text as superscript numerals and refer to endnotes for each chapter.

Finally, thanks are due to Gloria Simmons of Digital Typographers, Inc., of Gardena, California. Had we not been confident of her abilities, we might not have tackled this project; had she not exceeded our expectations, this volume could not have been produced in its present form.

Phyllis M. Grifman

Introduction

Much has been written over the past 20 years about the ways in which we manage, plan and otherwise preserve our coastal resources. Starting in the West, and especially in the U.S., those themes in the field that has become known as **coastal management** have resonated throughout much of the developed and developing world. We are now accustomed to speaking of coastal zone management, coastal resource management, shoreline management and coastal protection, all of which have similar meanings in the context of using wisely the limited coastal resources of the world.

Often, however, our discussion of these themes is constrained by our own parochial perspectives: one country, one province or state or even narrower jurisdiction. Our ability to adapt our own techniques for managing coastal resources and development further may be hampered by a lack of awareness of technological or policy advances in other parts of the world that could be used or adapted to our own circumstances. This volume seeks to spread the word about a few of those new techniques and policies.

The Coastal Ocean Space Utilization (COSU) conferences have been an effort by the U.S. government, working with major universities to expand that parochial perspective to include the experiences of other countries in managing their coastal resources. But the conferences have been more than that.

The two COSU conferences, first in New York in 1989 and then in Long Beach, California in 1991 have emphasized techniques for wise use of coastal resources including discussions of policy, technology and development of those resources. This volume reports on the results of the second COSU conference, COSU II, which was held in April, 1991 in Long Beach.

In three days of discussions, over 50 papers were presented by academicians, government officials and industrialists from 14 countries on methods by which their organizations utilized or protected the coastline in a new or novel manner. Naturally, because of the broad geographic representation at the conference, there were discussions that covered an extremely wide range of topics, from a new set of locks at the Panama Canal to land reclamation activities along the coast of Bangladesh. Some of the coastal development proposals that were discussed for nearshore areas of the world have actually been developed and others are very futuristic in concept and have yet many years to go before implementation. In many ways, the conference was a window to current thought among those most knowledgeable about coastal use trends.

Any book such as this, however, captures new ideas at one moment in time — in this case, April 1991. For example, one of our authors addresses future coastal zone utilization policies for the USSR, policies which retain remarkable currency in the Russia of 1993, but which have inevitably changed since Dr. Vartanov wrote his paper. We urge the reader to consider the temporal context in the few cases where it is as prominent as Dr. Vartanov's.

The papers are divided into thematic sections which are roughly equivalent to the sessions in which the papers were presented in Long Beach. In the cases where papers have been moved, it was clear that the topic under discussion related most closely with a group of papers presented at a different point during the conference. Often an abstract of a paper dictates its placement in a conference while the completed text dictates a more suitable location in print.

Some of the papers in this volume were not presented but were submitted for publication after the conference. They are noted by an asterisk (*) beside the title in the Table of Contents. They have been associated by subject matter in these proceedings with the papers that were presented at the meeting.

In the first section are presentations from the opening session, "National Reports: Status of the Coastal Zone." Not all countries are represented in this session, but we include papers from the Americas: Canada, the U.S., Mexico and Argentina; from the Pacific: Japan, Korea, Taiwan; and from the USSR. The papers were solicited to demonstrate the current status of work in each of these countries, each of which has a long coastline.

The next section addresses coastal development issues. In a series of papers from Japanese researchers and officials whose work involves land reclamation, we observe how technology affects development of coastal lands for recreation, water purification and residential use. Three additional papers discuss other aspects of coastal use, including a new set of locks for the Panama Canal, cost-effective, environmentally safe "harbors of refuge" for boaters, and the public and private benefits of creating coastal ocean theme parks.

The third section focuses on coastal policy issues, dealing with coastal sand and gravel mining in the U.S. and Canada and its impact on both the marine environment in general and on fisheries resources specifically. That discussion is followed by a three-paper suite on use conflicts between fisheries exploitation and coastal and offshore development. These papers emphasize the difficulty in providing a means of reaching accord between users of the coast whose uses are at times mutually exclusive. Another group of papers in this section addresses the social and economic implications of land reclamation in the coastal zone. Some land reclamation policies make badly needed land available in heavily populated coastal countries but there are consequences of reclamation, including the possibility of catastrophic loss of life to resident populations due to seasonal coastal flooding and inundation.

To utilize the coasts of the world for energy production and other uses, it is necessary to know as much as possible about the nature of the coasts and their adjacent waters. Thus, information on the consequences and risks associated with various coastal land and water uses includes ocean, coastal and weather data. In the fourth section we discuss new methods for coastal data acquisition and examine how that data might be used to improve resource management decisions. Included in this section are also papers on energy systems, desalinization, and ocean engineering.

One of the most important uses of the coast is for ports and harbors which can accommodate ocean-going cargo vessels. In the fifth section on port development and marine transportation, the discussion turns to questions of planning for marine terminals and seaports, shipping safety in near coastal areas, the future of marine operations in the Arctic, and discussions of a variety of floating or deployable marine structures for coastal use. But port development is not merely a technical issue; it also involves consideration of economic and environmental feasibility, both issues that are discussed in this section and which impose constraints on rapid port expansion.

In the sixth section, we expand on the multiple use conflict issues raised in previous discussions. Here we explore case studies of conflicts over uses and between jurisdictions in order to derive an acceptable level of coastal zone use both in the U.S. and abroad. State programs in the U.S. provide most of the examples of how these use conflicts can be managed, with one paper addressing an example from the Middle East for contrast.

In the final section, we present three papers on waves and their influence on the design of coastal structures, with an eye toward making better calculations of wave forces against all types of coastal structures, especially breakwaters.

We hope that this volume proves to be useful beyond merely memorializing the work presented at the COSU II Conference in 1991. Most, if not all, of the authors continue to work in the areas of marine science, engineering or policy and continue to contribute to their fields, including doing more work on the issues reported here. For that reason, we look forward to seeing modifications and new versions of the ideas presented in this volume.

Many colleagues and friends made the COSU II meeting and this volume possible and we want to acknowledge their help and advice. Charles N. Ehler, the Director of the Office of Ocean Resources Conservation and Assessment, NOAA/National Ocean Service and Norman Caplan, Section Head, Biological and Environmental Systems Division, National Science Foundation, made the funding available for the conference and for this volume, and we appreciate their support. Joseph R. Vadus, Senior Technical Advisor, Office of the Assistant Administrator, NOAA/National Ocean Service was our programmatic liaison with NOAA/NOS and NSF and was involved with us throughout the project. We appreciate his dedication to the COSU conferences and his help in making COSU II a reality.

This volume would not have been possible without the generous support of the Max and Victoria Dreyfus Foundation. Norman Portenoy, Director of the foundation, was instrumental in arranging funding for its publication and we deeply appreciate his support for the project.

Dr. Don Walsh of International Maritime Incorporated was the executive director of the COSU II conference. His efforts at organizing conference planning and implementation made it possible for USC Sea Grant to mount this effort with our small staff. We are especially indebted to him for his energetic and thoughtful approach in working with USC Sea Grant and we are happy to count him as one of our colleagues and friends. His aide, Ms. Kije, was also vital to our success.

The three luncheon speakers deserve special note. Dr. Sylvia Earle took time from her busy schedule as the Chief Scientist of NOAA to attend our meeting and speak on her experiences in marine science with special attention to the Kuwait oil spill cleanup. Dr. Willard Bascom, oceanographer and former Director, Southern California Coastal Water Research Project (SCCWRP) challenged us with his remarks on "The Non-Pollution of the Oceans." On the final day of the conference,

Herb Brand, Chairman of the Board of the Transportation Institute, made a presentation of the 1991 Paul Hall Memorial Award to the 1991 Paul Hall Memorial Lecturer, Professor Emeritus Clinton Whitehurst of Clemson University, who delivered his lecture at the luncheon.

It has been our pleasure to edit and craft this volume into its present form as a tribute to the good ideas about coastal management that were presented at the Second International Symposium on Coastal Ocean Space Utilization.

Phyllis M. Grifman
James A. Fawcett
February 1993

FINAL PROGRAM

COSU II
LONG BEACH, CALIFORNIA
APRIL 2-4, 1991

THE SECOND INTERNATIONAL SYMPOSIUM
ON
COASTAL OCEAN SPACE UTILIZATION (COSU II)

APRIL 2-4, 1991

Sheraton Long Beach at Shoreline Square

Long Beach, California

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San Pedro, California

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COSU II - FINAL PROGRAM

TUESDAY 2 APRIL, 1991

SYMPOSIUM REGISTRATION

Registration will be in the lobby area adjacent to the meeting room. The registration desk will be open at 7:30 AM and registrations can be accomodated at any time during the meeting. Coffee and tea service will be available in the registration area throughout the symposium.

MORNING SESSION

9:00-9:30

CONVENE THE SYMPOSIUM

Remarks:

Joseph R. Vadus
COSU II Symposium Co-Chairman
Office of Oceanography and Marine Assessment
National Oceanic and Atmospheric Administration (NOAA)
Rockville, Maryland

Port of Los Angeles Welcome:

Dwayne Lee
Deputy Executive Director for Development
WORLDPORT LA

Port of Long Beach Welcome:

Leland R. Hill
Managing Director, Planning & Engineering
Port of Long Beach

Administrative Information:

James Fawcett
COSU II Program Chairman
Acting Director
Sea Grant Program
University of Southern California
Los Angeles, California

9:30-12:00

KEYNOTE ADDRESS & NATIONAL SUMMARY PRESENTATIONS

Moderator: Charles N. Ehler, NOAA
COSUII Symposium Co-Chairman

Keynote Address: Improved Information for Coastal Ocean Decision Making: The U.S. Experience

Charles N. Ehler
Director
Office of Oceanography and Marine Assessment
NOAA
Rockville, Maryland

Argentina: National Oceanic Programs for Argentina: Basic Considerations

Ascensio C. Lara
Director
and Esteban L. Biondi
Ocean Engineering Center
Catholic University of Argentina
&
Albina L. Lara
Professor of Economic Geography
University of Belgrano
Buenos Aires, Argentina

Japan: A Strategic Concept for the Development of Coastal Space Utilization Technology in Japan for the 21st Century

Akiyoshi Yamaguchi
General Supervisor for Port Engineering
Engineering Division
Ports and Harbors Bureau
Ministry of Transportation
Tokyo, Japan

Canada: Canada's Policies & Programs for Coastal Ocean Space Development

Donald J. Patton
Professor, Centre for International Business
Dalhousie University
Halifax, Nova Scotia, Canada

Mexico: Coastal Ocean Space Development in Mexico

Roberto Bustamente
President
Mexican Society of Ocean and Coastal Engineering
&
Mauricio Porraz
General Secretary
Academy of Sciences of Mexico
Mexico City, Mexico

USSR: USSR Coastal Zone Utilization Priorities and Concerns of New Government Policies

Raphael Vartanov, Head
Economic Problems of Ocean Development Section
Institute of World Economy and International Relations
USSR Academy of Sciences
Moscow, USSR

TAIWAN: Coastal Engineering Research Activities in Taiwan

Shiang-Kueen Hsu
Acting Director
Division of Engineering & Applied Science
National Science Council
Taiwan, China

KOREA: Coastal Zone of Korea: Status and Prospects

Jihyun Lee, Yonghee Lee, Seoung-Yong Hong & Moonsang Kwon
Ocean Industry and Policy Division
Korea Ocean Research & Development Institute
Republic of Korea

12:00 - 1:30

LUNCHEON PROGRAM

"The Non-Pollution of the Oceans"
Speaker: Willard Bascom
Oceanographer
Long Beach, California
Master of Ceremonies: Andreas B. Rechnitzer
President
Ocean Centers International
San Diego, California
This luncheon is sponsored by WORLDPORT LA

1:30 - 5:30

DEVELOPMENTS IN COASTAL OCEAN SPACE

Moderator: Joseph R. Vadus, NOAA

Offshore Industrial Development Fisheries Mitigation: Its Effectiveness and Recommendations for Improvement

Eugenia Laychak
Principal, EJL & Associates
Sacramento, California

Ocean Space Utilization: Technology Trends and Future Concepts

Takeo Kondo
Associate Professor, Nihon University
Tokyo, Japan
&
Joseph R. Vadus
NOAA

Natural Resources Damage Claims Under CERCLA for Ocean Dumping and Marine Pollution

John J. Allen
Head, Environmental Practice Group
Graham & James
Los Angeles, California

Panama - A New Set of Locks

David F. Bastian
U.S. Delegate
Commission for the Study of Alternatives to the Panama Canal
U.S. Embassy, Republic of Panama

Data from the Coastal Zone: What is Planned by the National Data Buoy Center

J. Michael Hemsley, Chief
Program Management Division
National Data Buoy Center
NOAA
Stennis Space Center, Mississippi

"ODAIBA" Sea Purification and City Resort Concept

Yoshimi Nagao
Professor, Nihon University
&
Michio Morihira
Managing Director
Tokyo Waterfront Development Inc.
&
Kenji Hotta
Associate Professor, Nihon University
&
Hiroyuki Nakahara
Secretary General
Research Institute for Ocean Economics
Tokyo, Japan

Ocean Borne Waste Management Systems

Udi Saly
President and CEO
Flexible Environmental Systems, Inc.
Boston, Massachusetts

EVENING

INTERNATIONAL RECEPTION

6:00 - 8:30

Hors D'Oeuvres and No Host Bar
Sponsored by the COSU II Committees

WEDNESDAY 3 APRIL, 1991

MORNING SESSION

8:30 - 11:45

TRENDS IN RESOURCE DEVELOPMENT

Moderator: Charles Bookman, Director, Marine Board, National Research Council, Washington, D.C.

Environmental Implications of Sand, Gravel, Shell, and Placer Mining in the U.S. Offshore

Barry S. Drucker
and
T. John Rowland
Physical Scientists
Office of Strategic and International Minerals
Minerals Management Service
U.S. Department of the Interior
Herndon, Virginia

Multiple Use Compatibility: Commercial Fishing and Coastal Zone Development

Peter H. Fricke
Office of Fisheries Conservation & Management
National Marine Fisheries Service
NOAA
Silver Spring, Maryland

Addressing Oil and Fishery Conflicts: California's Local Marine Fisheries Impact Program

Michael A. Kahoe
Office of Offshore Development
Enviornmental Affairs Agency
State of California
Sacramento, California

The Potential for Fisheries Habitat Creation Through Marine Aggregate Mining in the Bay of Fundy, Nova Scotia, Canada

G.F. Terry Lay & M.C. Rockwell
Technical University of Nova Scotia
Halifax, Nova Scotia
&
G.B.J. Fader & R.O. Miller
Atlantic Geoscience Center
Geological Survey of Canada
Bedford Institute of Oceanography
Dartmouth, Nova Scotia

Benefits of Coastal Region Ocean Theme Parks

Andreas B. Rechnitzer, President
and Roger R. Tierney, Chairman
Ocean Centers International
San Diego, California

Development of Coastal Waste Lands Through Ocean Coupled Solar Ponds for Production of Power, Fresh Water, Marine Chemicals and for Raising Aquaculture Farms for Growth of Rural Economy in Developing Countries

J.S. Sastry, C.K. Gopinathan and Gajanan P. Naik
National Institute of Oceanography
Dona Paula, Goa, India

California's Water Shortages and Coastwise Transport of Water Supplies

John Barbieri
President
Natural Resources Company
San Pedro, California

Land Reclamation with Waste and its Use in the Port of Osaka

Youichi Nakamura
Chief, Planning Section
Comprehensive Planning Division
Port and Harbor Bureau
City of Osaka
Osaka, Japan

LUNCHEON PROGRAM

12:00 - 1:30

"The Exploration of Coastal Ocean Space"
Speaker: Sylvia A. Earle, Chief Scientist
National Oceanic and Atmospheric Administration
Master of Ceremonies: Joseph Vadus

1:30 - 5:00

COASTAL ZONE TECHNOLOGIES & ENERGY

Moderator: Takao Hirota, President, Coastal Development Institute of Technology, Japan

Practices, Possibilities & Impacts of Land Reclamation Activities in Coastal Areas of Bangladesh

Dilip K. Barua
Coastal Engineering Consultant
Land Reclamation Project
Netherlands International Cooperation
Chittagong, Bangladesh

Evolutional Trend of the Coastal Zone and the Influence of Climatic Fluctuations

Francesco Marabini and A. Veggiani
Institute of Marine Geology
National Research Council
Bologna, Italy

A Proposal for the Refreshment of Coastal Zone Utilizing Wave Energy

Hitoshi Hotta, Takeaki Miyazaki and Yukihisa Washio
Marine Development and Exploitation Research Dept.
Japan Marine Science and Technology Center
Yokosuka, Japan

The Future of Northern Sea Route Operations - A Western View of Problems and Opportunities

Captain Lawson W. Brigham, U.S. Coast Guard
USCG Headquarters
Washington, D.C.
and
Guest Investigator
Marine Policy Center
Woods Hole Oceanographic Institution

Improving Coastal Zone Decisions By Use of Improved Science and Technology

Orville Magoon
President, Coastal Zone Foundation
President, American Shore & Beach Preservation Foundation
Middletown, California

Desalinization Plants: The Benefits and Impacts of a New Ocean Use in California

James W. Rote
Principal Consultant, Office of Research
California State Assembly
State of California
Sacramento, California

Creation of New Offshore Space: Artificial Islands and Calmed Water Areas

Hideo Shimada
Chairman, Offshore Development Promotion Committee
&
Toru Tamura
Secretary
Offshore Development Promotion Committee
The Kozai Club
Tokyo, Japan

The Potential of Ocean Energy Conversion Systems for Island and Coastal Applications

Patrick K. Takahashi
Director, Hawaii Natural Energy Institute
University of Hawaii
Honolulu, Hawaii
&
Joseph R. Vadus
NOAA

PANEL DISCUSSION

5:00 - 5:30

ADJOURN

EVENING FREE

THURSDAY 4 APRIL, 1991

MORNING SESSION

8:30 - 12:00

MARINE TRANSPORTATION AND PORT DEVELOPMENT

Moderator: Robert B. Abel, President, New Jersey Marine Science Consortium

Development of a Floating Module: HMS

Takao Hirota, President
Coastal Development Institute of Technology
&
Hirofumi Inagaki, Deputy Director General
Second Regional Port Development Bureau
&
Yosio Mori, Chief
Keihin Port Construction Office
Tokyo, Japan

Deployable Waterfront Facilities

Glenwood Bretz
General Engineer
U.S. Naval Civil Engineering Laboratory
Amphibious Systems Division
Port Hueneme, California

How Do You Describe A Containerport?

Henry Marcus, Associate Professor
Department of Ocean Engineering
Massachusetts Institute of Technology
Cambridge, Massachusetts

Can a Proposed Marina be Linked to Wetlands Restoration: Planning of Marina del Rey & Ballona Wetlands in California

Dorothy Soule, Director
Harbors Environmental Project
Hancock Institute for Marine Studies
University of Southern California
Los Angeles, California

The Taiwan Area Deep Water Port Preliminary Planning Study

Ho-Shong Hou, Project Manager
and J.C. Chang, Project Director
Institute of Transportation
Ministry of Communications
Taipei, Taiwan, China

Redevelopment of Ports & Harbors in Hokkaido

Tsutomo Sudo
Planning Director
Department of City Planning and Promotion
Otaru City Office
Otaru, Hokkaido, Japan
&
S. Ozawa
Executive Director
Cold Regions Port & Harbor Engineering Research Center

Shipping Safety in the Coastal Oceans

Charles A. Bookman
Director, Marine Board
National Research Council
Washington, D.C.

A Design Manual for Floating Facilities in Japan

Akiyoshi Yamaguchi
General Supervisor for Port Engineering
and Yasutoshi Yoshimoto
Deputy Director
Engineering Division
Bureau for Ports and Harbors
Ministry of Transport
Tokyo, Japan
&
Shigeru Ueda
Chief of Offshore Structures Laboratory
Structural Engineering Division
Port & Harbor Research Inst.
Ministry of Transport
Kanagawa, Japan

LUNCHEON PROGRAM

12:00 - 2:00

THE 1991 PAUL HALL MEMORIAL LECTURE

Introduction and presentation by:
Mr. Herbert Brand, Chairman of the Board
Transportation Institute
and 1987 Paul Hall Memorial Lecturer

"In Search of an Enduring Maritime Policy"

Clinton H. Whitehurst, Jr.
Professor Emeritus
Clemson University
Clemson, South Carolina

This luncheon is sponsored by the Paul Hall Memorial Endowment of the University of Southern California

AFTERNOON SESSION

2:00 - 4:00

INSTITUTIONAL AND MANAGEMENT ISSUES

Moderator, James Fawcett, Acting Director
Sea Grant Program, University of Southern California

Managing Multiple Use in the U.S. Coastal Public Trust Waters

Walter F. Clark
Attorney, Ocean Law Specialist
Sea Grant Program
University of North Carolina
Raleigh, North Carolina

Coastal Zone Space: Invitation to Conflicts

Edward D. Goldberg
Professor of Chemistry
Scripps Institute of Oceanography
La Jolla, California

How to Resolve Coastal Multi-Use Land Conflicts: Approach and Examples

Peter Grenell
Executive Officer
California State Coastal Conservancy
Oakland, California

California Ocean Use Management: An Assessment of Two Integrating Approaches

James Lima and Michael McGinnis
Research Associates
Ocean & Coastal Policy Center
Marine Science Institute
University of California, Santa Barbara
Santa Barbara, California

Coastal Ocean Space Research and Utilization in the Middle East

Robert B. Abel, President
New Jersey Marine Sciences Consortium
Fort Hancock, New Jersey

An Assessment of Coastal Multi-Use Management and Training Programs in Rhode Island

Thomas H. Brillat
Coastal Management Specialist
Coastal Resources Center
University of Rhode Island
Narragansett, Rhode Island

GENERAL QUESTION AND ANSWER SESSION

4:00 - 4:45

Moderator: Robert Douglas, Dean of Natural Sciences and Mathematics, University of Southern California

and James Fawcett, COSU II Program Committee Chairman & Director, Sea Grant Program, University of Southern California

4:45 - 5:00

SYMPOSIUM SUMMARY AND ADJOURNMENT

Charles N. Ehler, NOAA, COSU II Co-Chairman

FAREWELL WINE AND CHEESE RECEPTION HOSTED BY THE COSUII ORGANIZERS.

TO BE HELD IN THE CONFERENCE AREA LOBBY

5:00 - 6:30

National Reports:
Status of the Coastal Zone

1

Improving the Information Base for Ocean Space Use Planning and Management

Charles N. Ehler
Office of Oceanography and Marine Assessment, National Oceanic and Atmospheric Administration, Washington, D.C.

It's a pleasure to be here in Long Beach on the edge of one of the most beautiful ocean areas in the United States — and the only place where offshore oil rigs are engineered to look like condominiums — only in California! I spent over two years of my early professional life teaching at UCLA and always enjoy getting back to the Los Angeles area.

One of the goals of this symposium is to improve the exchange of information about innovative ideas for ocean space planning and management. And I can think of no better setting in which to hold our meeting. Over the past 20 years, Los Angeles County has led the other 450 U.S. coastal counties in virtually every measure of development — single-family homes, apartments, stores, industrial buildings, and recreational facilities.. Between 1970 and 1989, more new single-family homes were built in Los Angles County alone than in 21 of the 30 coastal states!

It is also fitting that this symposium is being held near some of the best port facilities in the world — both the World Port Los Angeles and the Port of Long Beach. The National Oceanic and Atmospheric Administration (NOAA) appreciates the hospitality and willingness of World Port Los Angeles to co-sponsor this meeting. I also want to thank the other co-sponsors of this second Symposium on Coastal Ocean Space Utilization, including the National Science Foundation, the Coastal Development Institute of Technology in Japan, both the Sea Grant Program and the Paul Hall Endowment of the University of Southern California, and the Max & Victoria Dreyfus Foundation.

Almost two years have passed since the First International Symposium on Coastal Ocean Space Utilization, held in New York City in May 1989. The first

International Perspectives on Coastal Ocean Space Utilization
Phyllis M. Grifman and James A. Fawcett, Editors

symposium took place only a month after the spill of 11 million gallons of crude oil into Prince William Sound, and I had to leave the symposium early to return to work in Alaska. A lot has happened since that first conference.

The Hazardous Materials Response Program of the Office of Oceanography and Marine Assessment provided much of the key scientific information to the U.S. Coast Guard and to Exxon to guide many of the cleanup operations during the first two years.

As importantly, over the past two years, NOAA and the other public trustee agencies have fulfilled their marine stewardship responsibilities by mounting an extensive damage assessment program in South-Central Alaska. That effort culminated with a settlement agreement in which Exxon agreed to pay the Federal and State governments a billion dollars for injuries to marine resources — the largest environmental settlement in history. The settlement, as most of you know, was in addition to the over two million dollars that Exxon had already paid for cleanup over the last two years. That money can be used to enhance restoration of the natural resources of Prince William Sound, rather than to pay the fees of public and private attorneys over the next decade. The Exxon settlement, and others involving lesser amounts of damages, drive home the high costs of cleanup and restoration and the importance of good planning and pollution prevention before it causes extensive injuries to marine resources and their habitats.

Over the past decade NOAA's Office of Oceanography and Marine Assessment has improved considerably the information base for decisionmaking on the use of coastal and ocean areas of the United States. In 1991 we released a new report showing a continuing decline in the amount of approved shellfish-harvesting waters in the United States. That report, called the "1990 National Shellfish Register of Classified Estuarine Waters," shows that — as a percentage of the 19 million acres of classified waters — the approved acreage for shellfish harvesting dropped from 68 percent to 65 percent from 1985 to 1990. We attribute this continuing decline to a loss of wetlands, declines in water quality, over-harvesting, and some natural phenomena. Shellfish diseases, such as MSX and Dermo, and parasites such as oyster drills, have destroyed significant numbers of shellfish during periods of salinity extremes in estuarine waters.

Old and overloaded sewer systems continue to be a major factor in shellfish closures over the past five years. In many cases, improvements in estuarine water quality resulted from the use of ocean outfalls that move discharges further offshore. This concerns many shellfish sanitation officials since only four states (Maine, Massachusetts, New Jersey, and California) classify offshore waters for shellfishing purposes. These offshore waters are monitored only sporadically by state and local officials.

The impact of nonpoint pollution sources on shellfish-growing waters increased greatly from 1985 to 1990. Both urban and agricultural sources were important. The significant increase in the number of marinas in all states has prompted the Interstate Shellfish Sanitation Conference to establish minimum shellfish harvest requirements in waters adjacent to these boating facilities. Most states have imposed requirements beyond these minimums.

The downward trend in the harvest of naturally-grown oysters continued over the past five years, continuing a decline in production that has been occurring over the past 100 years. On the other hand, consumer demand for shellfish has been on the rise. Some harvesters, seeking higher yields to meet this demand, have over-fished natural beds — and handlers have been careless.

Because of the decline in natural production, the West Coast has turned almost entirely to aquaculture for oyster production. On the East and Gulf of Mexico coasts, clam aquaculture is increasing. But the move toward aquaculture has not diminished concern about water quality. Aquaculture practices in the United States commonly include the use of estuarine water, directly or indirectly.

The combination of rising consumer demand and declining production also has brought a significant increase in shellfish imports. About 60 percent of frozen shellfish products now comes from abroad. The American consumer now has a serious interest in the quality of coastal environments in those countries from which we are importing these shellfish.

Many estuaries of the United States are experiencing water quality problems ranging from anoxia and hypoxia, to changes in species diversity, habitat availability, noxious (sometime toxic) algal blooms, and fish kills. The United States does not have a license on this problem. Estuaries and coastal waters around the Mediterranean, in Southeast Asia, and Japan all report similar problems. Nutrient discharges from point, nonpoint, and sources upstream of coastal areas are at least partially responsible for this decline in water quality. The dramatic growth of coastal populations, the pressure to increase agricultural production through fertilization, the conversion of wetlands into fields and urban areas all contribute to the problem. However, although the consequences of nutrient enrichment are recognized as a major coastal pollution problem, the effects attributed to nutrient loadings are equivocal and the extent of the problem remains unclear.

In cooperation with the University of Rhode Island and with funds from the Environmental Protection Agency, the Office of Oceanography and Marine Assessment now is conducting a nation-wide data survey and synthesis designed to quantify the degree and geographical extent of eutrophication in the estuaries of the United States. I'll report on the results of this work at our next symposium.

Not all of the news from the United States is bad. In 1991, the NOAA Office of Oceanography and Marine Assessment released a report on "Coastal Environmental Quality in the United States" that reported on the status and trends of chemical contamination in sediments and tissues of selected bottom-feeding fish and mussels and oysters. After six years of sampling systematically at about 300 sites throughout the United States, we concluded that, on a national scale, high and biologically significant concentrations of contaminants measured through NOAA's National Status and Trends Program were limited primarily to urbanized, estuarine areas. In addition, levels of those contaminants, in general, appear to be decreasing when compared to results from a similar effort undertaken in the mid-1970s by the U.S. Environmental Protection Agency. The contaminants that we measure through the program include seven trace metals and the organic compounds such as DDT, chlordane, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons

(PAHs). In cooperation with the International Oceanographic Commission, we will support similar "Mussel Watch" work in Central and South America.

These apparent improvements must be interpreted in the context of rapidly increasing coastal populations and developing coastal areas. Most of the world's coastal areas are under increasing pressures from population growth and related economic development. In the U.S.A., about 110 million people, almost half of our total population — now live in coastal areas. By the year 2010, coastal population will have grown from 80 million in 1960 to more than 127 million people, an increase of almost 60 percent. Some of our states, including Florida, will have increased more than 200 percent during that period. Seventeen of our 20 fastest-growing states are coastal. During the 1980s, California, Florida, and Texas together accounted for 73 percent of the population growth in coastal areas in the United States.

The coastal land area of the U.S.A. comprises only 11 percent of the national total (excluding Alaska). Coastal population density is now about 350 people per square mile, more than four times the national average. The largest percent change in population density over the next two decades is expected in Florida, primarily along the state's Gulf of Mexico coast. Continued population growth in coastal areas portends increased crowding of this relatively small, but densely populated, portion of America. The dilemma of balancing this growth with sound coastal management is becoming an increasing national concern in the United States.

To reduce conflicts among competing land and water uses in coastal areas, while protecting sensitive coastal and marine resources, the U.S. Congress passed the Coastal Zone Management Act of 1972. Under its authority, NOAA manages the only national program to plan comprehensively for — and manage development of — coastal land and water resources of the U.S.A. Today 29 states and territories, covering 94 percent of our coastline, have received federal program approval and are implementing their programs. These state-operated programs seek a reasonable balance between the preservation and protection of coastal resources — and the development of those resources.

Since 1974, the Federal government has invested over $600 million in state coastal zone management programs. Significant benefits have resulted from this public investment in the form of protecting life and property from natural hazards, guarding fragile coastal habitats, improving public access to the coast, preserving and encouraging water-dependent uses such as ports and marinas. Many of the state coastal management programs have assisted port authorities in assuring that adequate land is available for port operations, and in obtaining and identifying dredged material sites in an environmentally acceptable manner.

Based on their experiences with coastal management, several states — including California, Oregon, and Washington — are beginning to extend their coastal planning activities to ocean areas. Oregon, in particular, has made a significant effort to develop an ocean resources management plan. This, and other state programs, are experiments that deserve our attention and support.

Many coastal communities have grown in the form of development that has sprawled across the landscape. Barrier islands have become a mecca for retirees and vacation home-owners. Coastal wetlands have been filled for housing developments and have had their waters directed into canals. The natural processes of coastal ecosystems have been disrupted by poorly planned or inefficient development patterns. Consequently, both the ecological and economic values of coastal areas are threatened as coastal development increases.

In the fall of 1991, NOAA released a report summarizing twenty years of residential and commercial development in coastal areas. The report is an assessment of the mixture and distribution of development at the regional, state, and county level. The data are derived from the place-level permit data base of the Bureau of the Census.

Preliminary findings from the report reveal that between 1970 and 1989, 46 percent of U.S. residential growth occurred in coastal counties — almost half of the growth in residences in only 10% of the land. These areas also accounted for 40 percent of the nation's commercial and industrial development. As I mentioned earlier, over the past 20 years, Los Angeles County has not only led the 451 U.S. coastal counties in virtually every measure of development, but it alone has built more new single-family homes than 21 of the 30 coastal states!

While direct causes of environmental quality problems are often difficult to document, evidence is mounting that many are the result of general coastal development patterns. Like eutrophication, this problem is not unique to the United States. A 1990 report of a United Nations-sponsored Group of Experts on the Scientific Aspects of Marine Pollution (or GESAMP), concluded that "...while open areas of the sea remain relatively clean,...the margins of the sea are affected by man almost everywhere. Habitats are being lost irretrievably to the construction of harbors and industrial installations, to the development of tourist facilities and mariculture, and to the growth of settlements and cities....If unchecked, this trend will lead to global deterioration in the quality and productivity of the marine environment."

Natural processes of coastal ecosystems are being disrupted, and the ecological and economic values of coastal areas threatened. Fundamental changes are occurring in the way natural systems work and look. As population grows throughout the world's coastal areas, many of the qualities that attracted people to them initially are diminished.

Coastal and marine places are undergoing profound changes from Florida to France to Japan. Because of these changes, coastal residents have become more sensitive to the places in which they live, more demanding of the quality of the coastal environments, and more alert to the side-effects of development.

The technology is now available to make irreversible environmental changes over huge areas. We have the ability to construct projects about whose environmental effects our knowledge is extremely limited. Although our knowledge about the ocean is growing, our ability to modify its natural systems is growing at an even faster pace.

Changing people's motivations is no easy task. Developers, whether private or public, are accustomed to having the status and success measured by the "bottom line" of their financial statements. Countries all over the world seduce developers with tax incentives or subsidies promising immediate returns on investment. In contrast, the rewards for producing development of long-range quality may be many years away. Developers must be convinced — through appropriate incentives — that the maintenance and enhancement of a quality experience is a more important goal than immediate cash flow. Quick returns are tempting, but in the long run a developer's reputation rests on the lasting qualities of what he creates.

The true costs of the development of coastal and ocean space, including the costs of research, permitting, and monitoring, must be more fully internalized by developers. A system of liability and other economic incentives should be developed that will force developers to look toward the long-term. If a project degrades the coastal and marine environment — or displaces another desirable use of these areas — then the developer should be liable for damages.

From countless once-special coastal areas the world over, people have withdrawn. Eventually, citizens judge and act — with their feet and wallets. And, fortunately for the future of these special coastal areas, the long-term interests of residents and visitors — and thus of developers — can further sound planning, conservation, and a high standard of environmental protection.

Two years ago I said that there were no short cuts to developing a body of information and new tools for ocean space use planning and management. The task of integrating disparate data bases, organizing information, developing new knowledge, and taking advantage of new technology requires creativity, consistency, and continuity. That message hasn't changed and that's what this symposium is about.

I've used many times the analogy of the development of the compass, and how poorly it was used for navigation when it was introduced to Portuguese mariners in the 13th Century. We remain in the same boat.

We attempt to regulate the discharge of pollutants through a source-by-source, pollutant-by-pollutant approach. We don't manage nonpoint sources and their organic loads at all. We permit the destruction of important wetlands through individual permits that on their own merits seem trivial, but when added up amount to the destruction of coastal habitats as we know them and upon which coastal and estuarine animals that we value highly absolutely depend. We see declining populations of important commercial and recreational species of fish and shellfish, but our response is to manage them on a species-by-species basis with little thought given to their habitat requirements. We see increasing use conflicts in coastal and ocean areas — between fishing and habitat conservation, between marine transportation and recreation, and so on — and we continue to manage these uses on a single-sector basis.

Business as usual is not going to be good enough. We need many changes in the way we do business, and an obvious one is to begin analyzing and managing ocean space — not by focusing on the pieces, but on a system-wide, integrated basis. We should promote the efforts of coastal states to develop coastal management plans. We should watch some of the efforts of NOAA's National Marine Sanctuary Program as it develops management plans for the Florida Keys and larges sanctuaries on the West Coast. We need our best scientists to help managers make the best use of what we know about coastal and ocean areas to improve our abilities to manage these areas. We need our best engineers to help us employ the latest in ocean and information technology to develop resources in an environmentally-sound manner. We need concerned and informed environmental groups and citizens and politicians, in general, to keep us on our toes.

That's what this Second Symposium on Coastal Ocean Space Utilization is all about — to bring cutting-edge scientific and engineering concepts together to talk about new information and technologies for managing ocean space.

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National Oceanic Programs for Argentina Basic Considerations

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ABSTRACT

The paper delineates a basis for designing National Oceanic Programs in Argentina. It summarizes the recent origins of ocean engineering as an organized discipline and its very rapid development; it also emphasizes the impact of ocean engineering on the economy and society. It is noted that today (due to causes such as the robotization of submarine activities) begins a decade with unsuspected possibilities for accelerating the progress of the country.

Oceanography and ocean engineering began sequentially, but nowadays both show important developments. For this reason it is possible, with the collaboration of both disciplines, to prepare oceanic programs in the medium and short run with specific objectives of resource exploitation and use and protection of the ocean space; notwithstanding the preparation of long term programs.

A reference to the human, physical and economic geography of the Argentine Republic is made to summarize its essential features. According to the characteristics and present circumstances of Argentina and the diverse possibilities of using the ocean, some priorities are indicated: offshore production of oil and gas, nearshore port and harbor operations, different uses of the ocean space, new ocean sources of energy, exploitation of living resources of the sea, etc.

It appears that we face one of the greatest opportunities to accelerate the economic, social and cultural development of the country. The ocean now offers us unexpected possibilities to satisfy our needs. International cooperation can play a very significant role in enlarging, accelerating and optimizing the capacity for undertaking ocean projects.

International Perspectives on Coastal Ocean Space Utilization
Phyllis M. Grifman and James A. Fawcett, Editors

INTRODUCTION

According to current technological possibilities, Argentina must undertake agressive development of its ocean space. It must thus elaborate a national oceanic program and include both research and development as well as professional activity in the area of modern ocean engineering. This paper seeks to reflect on this matter with a view toward contributing to the establishment of basic criteria for the elaboration of a national program. One of the first priorities issuing from the great wealth of the Argentine ocean is its potential for important ocean undertakings that will have strong socioeconomic impacts. There are interesting possibilities both in multiple and integrated use of Argentina's ocean space as well as in other specific and individual uses. All this must go hand in hand with adequate development of human resources. Recent and outstanding technological developments made by ocean engineering present enormous possibilities for social and economic growth for Argentina.

OCEAN ENGINEERING

Present-day ocean engineering has reached huge proportions. It is, nevertheless, a recent phenomenon, one of the so-called new fields of engineering.

Regarding the areas of interest discussed in this paper, we may say that the field was born in the early 1960s. Its growth since then has been surprising and its achievements colossal. We now have fixed offshore platforms with a height of over 400 meters, and the exploitation of ocean oil resources has expanded to reach water depths of over 600 meters (1800 feet). The technology used to reach ever greater depths is continuously being developed. A simple illustration of the growth rate in the field is that of the oil production platforms of the North Sea, whose maximum height in 1969 was no greater than 25 m (75 feet) of water depth.

Ocean engineering is a recent discipline that accelerates economic growth. For example, taking into account only one of the ocean resources — hydrocarbons — we can mention the case of Norway. In 1982 that nation produced 45% of the total net import of gas of all Western Europe with fast development of offshore production. Furthermore, in 1983 the petroleum sector accounted for 20% of the total state revenue.[1]

Brazil is another example of how ocean technology has a deep impact on economical development. Offshore oil reserves of the country grew from zero in 1968 to 100 millon cubic meters in 1979, representing more than 50% of the total reserves.[2]

Current automation of submarine activity by robots will most certainly give momentous impulse to oceanic undertakings and revolutionize advances in ocean science and technology.

OCEANOGRAPHY & OCEAN ENGINEERING

The "Challenger Campaign" (December, 1872)[3] is, no doubt, the starting point of an important scientific activity in the oceanographic field which has reached advances similar to those of modern science in general. In recent decades, ocean engineering has developed vehicles, habitats and underwater systems that let oceanographers (marine biologists, marine geologists, etc.) go down to the ocean floor to make direct observations, take measurements and take direct samples. This represented a great advance in the frontiers of the knowledge. A closer link between oceanography and ocean engineering will accelerate knowledge of ocean space.[4]

What we now call ocean engineering was born some three decades ago. Mankind now has Oceanography (Basic Sciences of the Sea) and Ocean Engineering (Applied Sciences of the Sea) at its service. The former lets us know how the ocean space is, the latter creates the knowledge to act in that rich and extended space. Both disciplines are mutually enriched by research and development though permanent interaction. But ocean engineering is also a profession consisting of the construction of specific structures and systems for production and of the construction of an infrastructure needed for economic growth and general progress. Ocean engineering contributes to the progress of science by creating constructions that can foster the expected socioeconomic impact.

In its scientific field ocean engineering has made it possible to complete the flow of knowledge from basic research to technological innovation, including applied research and development. This encompases basic research through technological innovation.

In its professional field, ocean engineering has put into practice technological innovations and oceanic constructions, through the design, construction, operation and maintenance of ocean systems.

The cycle of knowledge and the operation of ocean enterprises thus completed, we can now develop oceanic programs with specific socioeconomic goals. These programs can now take into account the medium and short run, as well as the long run projects related to basic research.

Usually, in the more developed countries where scientific policy is in harmony with general national policy, this integration and application of oceanic knowledge was included in scientific and social programs with no delay. In developing countries this incorporation must be carefully stimulated. Argentina, with its recent development of technology, may serve as a model and add its impulse to optimize development by means of science.

ARGENTINA'S GEOGRAPHY — ITS ESSENTIAL FEATURES

An Oceanic National Program must be based in the human, physical and economic geography of the country. Argentina occupies most of the southern portion of South America. It is the eighth largest country in the word, with an area of 2,800,000 square kilometers (1,073,000 square miles). This great length encompasses regions of remarkable diversity, including the formidable and continuous Andes Mountains; the dry lowlands of Gran Chaco; the broad fertile plains of the Pampa; and the immense, cold, and windy Patagonia. In its landscapes, its natural resources, and in its economic activities, Argentina presents regional variety and richness; yet it exhibits its own identity, based on a unity of culture, with roots in a common past.

On a world scale, Argentina has an isolated geographical position, away from the main economic centres. But at a subcontinental scale, Argentina is in a central position, surrounded by five countries. In this way, the country can be perceived as a large peninsula, with a continental and an oceanic destiny.

Argentine proximity to the Pacific-Atlantic "chokepoint" gives the country a strategic role in the global maritime pattern of communication.

Argentina posesses a coastline of 4,497 km, 384 of which corresponds to the River Plate littoral and 4,113 km to the Atlantic one. Figure 1 shows the Argentine seashore and South Atlantic Ocean.[5] The significance of having such an extended marine littoral is obvious. For exploiting the Argentine Sea, first we need to know it deeply and perceive it as being part of our territory, so it is the time for us to produce a "Blue Revolution." (This concept was used by Belaúnde Terry in the sense of transforming marine space into a human landscape).[6]

Population

The population of Argentina (32,425,000 in 1989) has increased more than 17 times since 1869, when the first census recorded 1,800,000 people. This rapid growth began to decline after the early part of the 20th century as both birthrate and inmigration began to diminish. Argentina's birthrate and growth rate are among South America's lowest and below the world average. The percentage of young people has declined proportionally; today those 15 years old or younger make up a mere 31% of the total population.

The nation's population density is also among the continent's lowest (only about 12 persons per square kilometer — 30.2 persons per square mile, in 1989), although certain areas are quite heavily populated, as the industrial area of the Humid Pampa, where almost half of the population is concentrated. The population is growing faster in urban areas, especially in Buenos Aires and the capital cities of the provinces, than in the rest of the country. Eighty-five percent of the population lives in urban areas, about a third in Greater Buenos Aires alone.

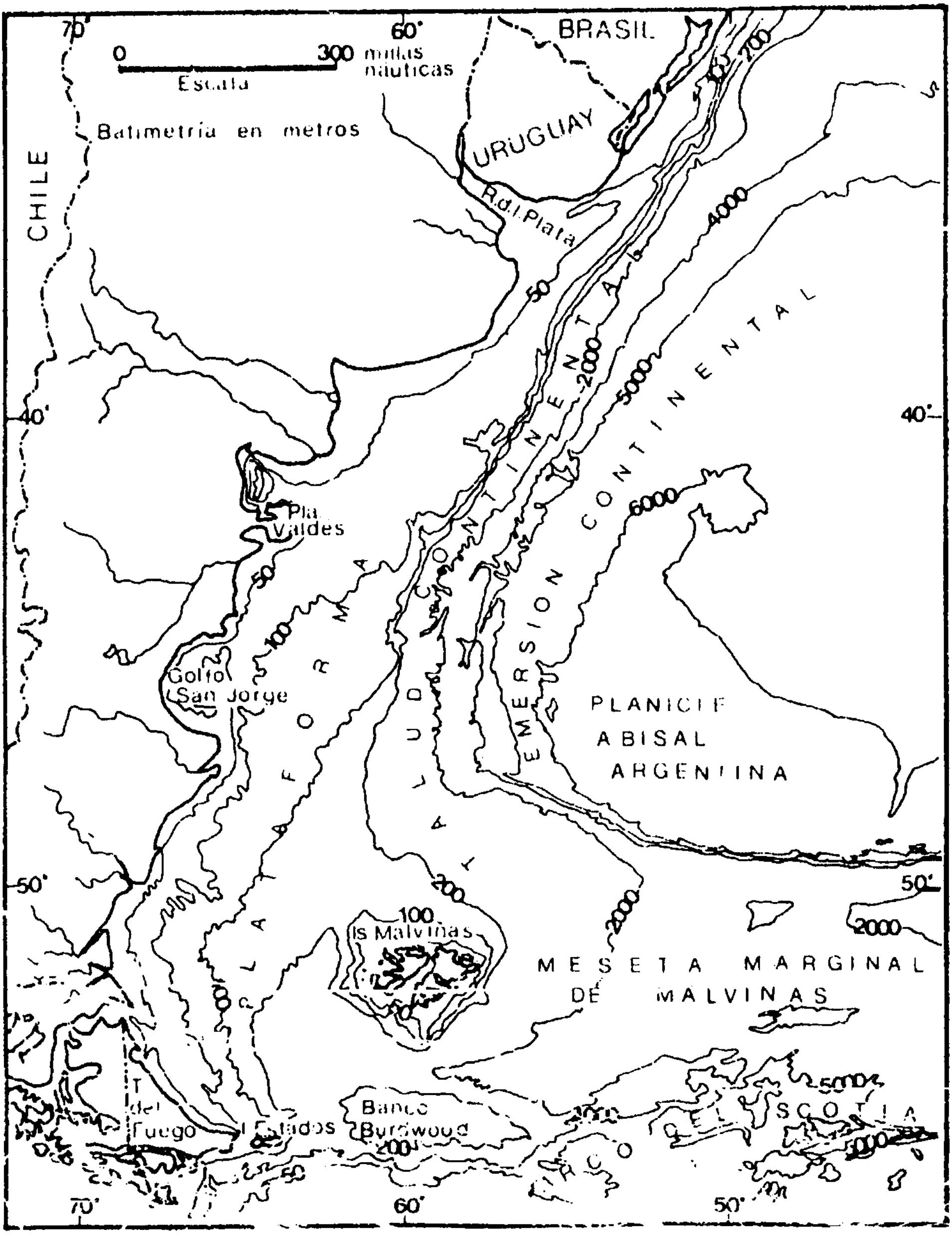

Figure 1. Argentine Seashore and South Atlantic Ocean

Source: Rey Balmaceda, Raul[5]

Economy

In the middle of the 19th Century the base of Argentine agriculture shifted from livestock to crops. The spread of wheat, corn, and flax organized the "estancia" (ranch) in the Pampa, the largest fertile area in the continent.

Although agriculture in this area did not become as intensive as in North America and Europe, soils were good and lands abundant. Argentine industry became significant when manufacturers developed food products for export and the country became one of the most prosperous in Latin America. Meat and crops were exported to the expanding markets of Europe in exchange for fuel and manufactures.

In the early decades of the 20th century Argentina became the world's leading exporter of corn, meat and flax. However, prosperity was reduced by World War I and the Great Depression of the 1930s, which damaged the Argentine economy by reducing foreign trade. The various governments then followed an import-substitution strategy during the next 40 years, designed to transform Argentina into a country self-sufficient in industry as well as agriculture.

By 1960, manufacturing contributed more to the country's wealth than did agriculture. Argentina had become largely self-sufficient in consumer goods, but it was also more dependent on imported fuel and heavy machinery. The government then invested intensely in such basic industries as petroleum, natural gas, steel, petrochemicals, and transportation.

By the mid-1970s Argentina was producing most of its own oil, steel, and cars and also exporting some manufactures. Manufacturing became the largest single component of the Gross Domestic Product (GDP), (38.3% by 1974). The country also had become self-sufficient in fuel while it remained one of the world's major agricultural producers. At the same time, inefficient production and management produced chronic inflation that rose until, in the 1980s it briefly exceeded an annual rate of 1,000 percent. Successive regimes attempted to control inflation through different strategies.

The period of import substitution ended in 1976, when an economic adjustment program lowered import barriers and liberalized restrictions on foreign borrowing. The measures implemented were intended to control inflation and increase efficiency by forcing competition. Instead, imported products were so cheap that many manufacturers could not compete at all. Between 1974 and 1984 manufacturing's share of the GDP declined from 38.3 to 21.4 percent.

The decline of the relative importance of industry is also evident when considering Latin America. Argentina produced about 31% of the Latin American Gross Industrial Product in 1950 and only about 17% in 1979.

In the 1980s the industrial recession became significant, giving as a result an industry partially integrated and considerably dependent on imported inputs and technology.

The economic adjustment program caused another serious economic problem: a huge foreign debt. The overvalued "peso" made exports expensive, so that exports earning could not keep up with the increasing debt. The country has agricultural and industrial sectors similar to those of developed countries, but they are remarkably less efficient. And despite a high standard of living by Latin America standards, Argentina is one of the heaviest debtors among Third World countries.

Energy Resources

By the late 20th century the country was self-sufficient in power, even to the degree that if could become a power exporter. The two main sources of power are petroleum and hydroelectricity.

The San Jorge oil basin around the Patagonian port of Comodoro Rivadavia is estimated to have about one-third of the country's onshore reserves. Nineteen oil basins have been recognized, but only a fraction of them have been explored. The onshore basins cover 1,337,450 square kilometers; the offshore ones 395,720 square kilometers.

Most of the country's power has traditionally been derived from oil, nevertheless, 50% of the country's energy reserves lie in the potential of its rivers. Hydroelectric power was increased by 10 times in the 1970s and large projects, such as Yacyreta-Apipe in the Parana River, are now under construction.

Nuclear power, promoted by the National Committee Atomic Energy, provides 12.4% of the energy. Argentina is a Latin American leader in the generation of nuclear energy.

Agriculture and Forestation

Meadows and pastures cover a half of the total area, while cultivated area accounts for 13% and forested for 22%. Figures for individual provinces vary sharply: from large percentages of agricultural land in Buenos Aires to virtually none in some arid areas. The Humid Pampa, where yields per square kilometer and per man are high, differs from the extensive system used in much of the country.

Argentina is one of the world's major exporters of wheat and soybeans, as well as meat. It is also one of the largest producers of wool and wine. Wheat and corn are Argentina's largest crop in harvested land area.

Argentina's industries have grown mainly along the River Plate littoral and along the coast in Buenos Aires and nearby cities, where most workers, the largest market and the principal port are located. Nevertheless, some industries can be found in the provinces, for example, petrochemical industries in Mendoza, close to oil fields, or a developing aircraft industry at Cordoba. In 1986 the most important manufacturing industries were: food, beverage, and tobacco (25.1%), machinery (24.5%).

Fishing

The Argentine Sea has about a millon square kilometers, and is assumed to contain some 300 species. Its marine biomass (statistical data from the Dirección

Nacional de Pesca Marítima) for commercial species is 12,072,657 tons and its maximum continual output is 2,156,537, according to Espoz Espoz,[7] (Data from Servicio Nacional de Sanidad Animal SENASA 1985) and 3,000,000 following FAO.

The maximum catch values allowed are established by the Fishery Subsecretary based on studies done by the Instituto Nacional de Investigacion y Desarrollo Pesquero (INIDEP). In 1979 they established a limit of 1,100,000 tons per year and in 1984 of 600,000 tons per year. This reduction was caused by overfishing, by the exclusion zone around the Malvinas Islands and by the impossibility of Argentine fishing companies to augment their catches.

The catch for 1987 was 450,657 tons, according to the Dirección Nacional de Pesca Marítma. This amount should be increased by 100,000 to take into consideration the non-registered catch allowed under provincial jurisdiction which extends 15 miles from the coast. Another 109,712 tons should also be added for that year to account for international agreements with USSR and Bulgaria. All of this adds up to 660,369 tons in 1987, which is an historical record for fishing activity.[8]

The capacity of the current fishing fleet was 1,151,155 tons in 1985, but 50% of it is non-operative due to obsolescence, damage and current low demand.

Along the coast of Buenos Aires (from 350 S to 410 S), the main capture species are hake, anchovy, striped tuna, corvina, "pescadilla" and tuna. The main fishing port of that zone is Mar del Plata, which handled 73% of the total catch in 1985. Eighty-four percent of fish processing plants, which concentrate on preserves and salting, are located in the region.

The use of ports is far better distributed in the area of frozen products and factory vessels. These sectors — highly technical and in expansion — have the benefit of being able to act in a wider range of catch zones and to act as delivery centers to foreign countries.

The new fishing industry centers are mostly located along the Patagonian coast. This is due to government incentives for industrial settlement in the region and to the promotion of exportation though those ports. As an example, 17 new plants were established in recent years in Puerto Madryn and 11 more are projected or under construction.[9]

The coastal regions of Patagonia and Tierra del Fuego account for 60% and 15% of the total coastline. The most caught species are hake, cod, "polaca," southern hake, and "granadero." Neither the ports nor the fishing fleet of the region are at the level of the Buenos Aires sector.

Until the beginning of the 1960s, the maritime fishery was only oriented towards the national market, and based on the coastal fishing fleet, with small ships. The beginning of deep sea fishing, based on heavy participation by foreign companies, made fast access to the international market possible. From 1963 on, deep sea fishing became more important than coastal fishing; in recent years, 70% to 80% of total maritime fishing. This change took place because of the initiation of exportation. Coastal fishing could not overcome the limitations imposed by a small internal market; while obsolescence is another restriction to its expansion.

The actual productivity of fishing — although it is related to biological richness — is highly limited by the technology applied. Modern technology lets a biologically rich region become economically rich. That is why we consider it important to mention that the fishing sector is one of the few of the non-traditional regional activities — with high incidence out of the Pampa region — that has recently shown growing capacity, incorporation of high technology and industrialization processes in areas with no fishing industry activity aimed at exportation.

Patagonian ports are the most favored in the current trend of investments, both for non-conventional deep sea fishing ships and for fish processing industries. In spite of the progress achieved based on an ever-growing penetration of the international market, the deep sea fishing fleet needs to be renovated and to increase its catch potential.[9]

The income for total exports of fishing goods in 1989 was $280 millon dollars. Nevertheless, it is still necesary to improve the legal framework of this activity in order to protect fishing resources and favour investments.

Squid is one of major catches of South Atlantic fishing. Its estimated annual volume for the region is of 550,000 tons. Argentina's participation in that catch is a mere 20,000 tons, although there are signs of progress in this fishery. According to the Argentine Agriculture Subsecretary, the country's annual participation could reach up to 100,000 tons.

There are many existing fish processing industries making use of higher technology and principally aimed at foreign markets. This is the case of the Surimi and Kumikama production plants. These products are obtained from hake, but their final international price is around three times that of hake.

Approximately one-third of Argentine fishing industry exports are currently destined for the European Economic Community (EEC). In 1992, however, the EEC will impose tougher sanitary requirements for its market, requirements most difficult to meet by present-day Argentine industry standards.

It is important to note that on December 28th 1990, Argentina and Great Britain, in mutual agreement, decided to ban commercial fishing in a semicircular marine area to the east of the Conservation and Fishing Administration Zone, created by London in 1986, which surrounds the Malvinas Islands. The ban's main aim is to halt the depredation of squid (especially ilex) carried out by ships of other countries.

Trade

Argentine trade has always been oriented toward Europe and the United States. In the last years, trade with Britain diminished, especially after the Malvinas war in 1982. Since that war, continental European countries (particularly the Netherlands and West Germany) and the Soviet Union have become important trading partners of Argentina, although the United States remains the single most important market for the country's exports. Brazil also ranks high in trade volume with Argentina.

Agricultural products (cereals, animal feed and vegetable oils) represent 40% of Argentina's exports. Argentina depends on machinery, transportation of equipment and chemical imports.

Education and Culture

The Argentine population is highly educated, which is reflected in the large number of schools and a high literacy rate (95%). Higher education, even though seriously hampered by economic crises and political problems, has high standards in Latin America. In comparison to the developed world, however, the public expenditure on education is low (2.7% of GNP).

PRIORITIES FOR A NATIONAL PROGRAM

It is prudent to establish some priorities among the enormous variety of resources and the possible uses of the ocean space. We must also define some priorities among geographic zones because it would be impossible to include them all simultaneously. This is particularly obvious in Argentina, which has a very long coastline and an enormous continental shelf.

The ocean offers to mankind ever-growing resources. The ocean was a resource for food and transportation centuries ago. Today those resources have grown enormously and many other new ocean resources can be used, thanks to technological progress. Table 1 shows a list of ocean resources.[10]

Among these resources, and keeping in mind the singularities, interests and the circumstances of today's Argentina, we have selected the following work areas:

- oil and gas offshore production
- coastal and near shore development (including offshore port and harbors, airports, etc.)
- living resources
- other uses of the ocean space (barges for industrial plants and other uses: recreation, etc.)
- renewable ocean sources or energy
- fresh ocean water and usable ocean water
- waste disposal and pollution control.

Table 1

Oceanic Resources

LIVING	Animals	food
	Vegetables	food bioenergy
NON-LIVING	Water	tidal energy thermal gradient energy wave energy currents energy salinity gradient energy usable water salty water (refrigeration-irrigation) fresh water (human use) self cleaning of wastes industrial building space
	Sea botton and ocean subsoil	oil gas coal manganese nodules phosphorus nodules heavy metals construction materials sites for storage
	Ocean as Space	transportation communications recreation industrial plants ocean farms human habitats

Oil & Gas Offshore Oil Production

In March 1990 the offshore production of oil and gas in Argentina began with the installation of the Hidra complex. Figure 2 shows the offshore sedimentary basins in Argentina, where the identification and evaluation of the resource will be allowed as exploration works continue.

The Argentina Continental Shelf, where most of these basins are located, has less than 200 m water depths and is expected to have important reservoirs of oil and

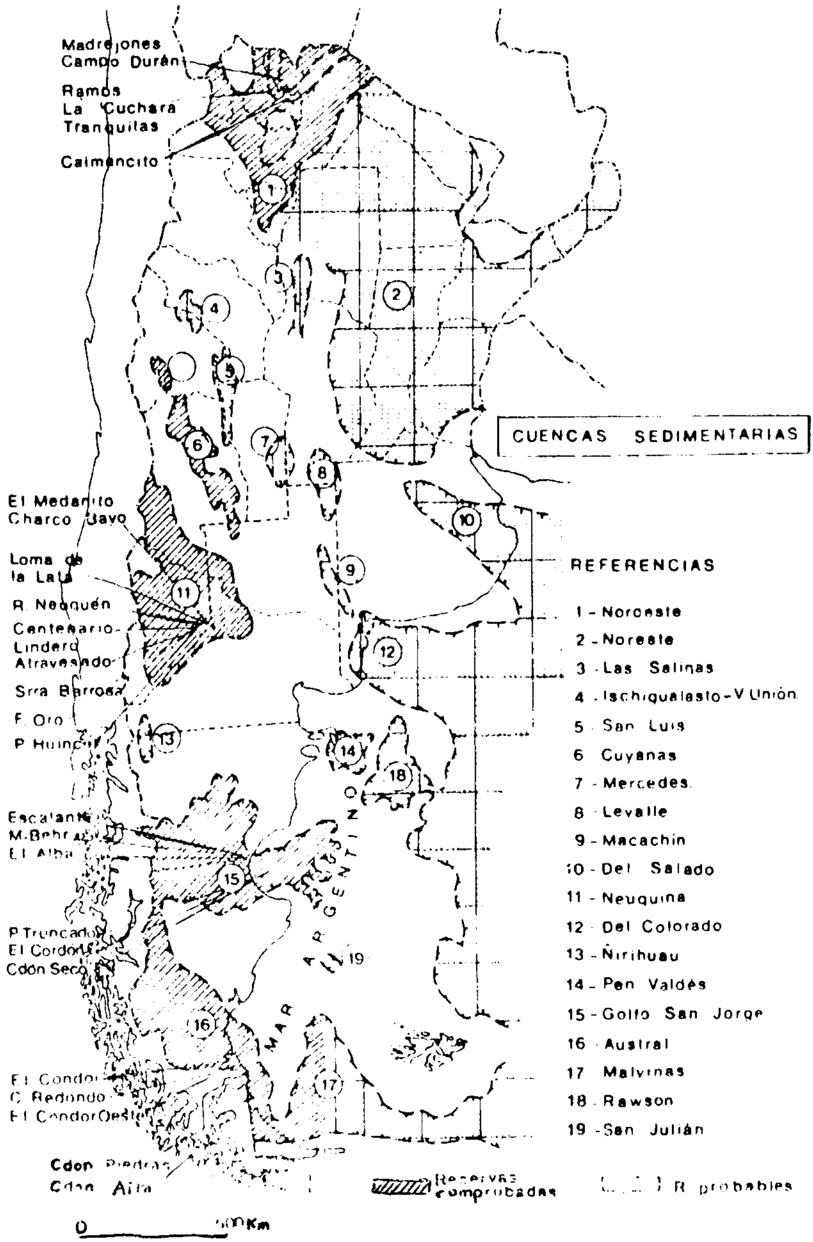

Figure 2. Sedimentary Basins
Source: Dozo, Servando[11]

gas. This means that the main offshore oil and gas basins are at water depths where current production and transport technology may be used.

The Continental Slope also has possibilities for oil exploitation, but is far from the coast and at deeper water depths. At the moment it seems that a deeper analysis of this basin is not a priority, until the basins of easier exploitation are more thoroughly studied.

Renewable Ocean Energy Resources

With various possibilities in the production of offshore energy, the Argentine Oceanic Program includes tidal and wave generated power. The choice of these two important potential power sources results from the climate and other geographical characteristics of Argentina on one hand, and depends on the extent of the development of specific technologies and power requirements (local and global) on the other.

Tidal Energy

The extended seashore of Argentina has many of the geographical singularities needed for the placement of tidal energy power plants. In Table 2 we show a list of the sites in Argentina mentioned by W. W. Wayne Jr. as suitable for potential tidal energy power plants.[12]

Table 2

Sites in Argentina for Potential Tidal Energy Projects

Location	**mean tidal range (m)**	**annual energy output (millon kWh)**	**plant capacity (MW)**
Golfo San José / Golfo Nuevo, Valdez Peninsula	6.0	9,000	1,000
Santa Cruz River	7.5	4,000	1,200
Puerto Gallegos	7.5	2,000	600
San Julian	6.0	400	130
Deseado Estuary	3.5	700	200

Roger L. Charlier[13] looks into these possibilities in some detail. In relation to the Valdez Peninsula he mentions the study by Sogreach (1959) predicting a 4965MW capacity single cycle power plant or 6820MW capacity double cycle power plant. He says that a tidal power plant in the Valdez Peninsula, combining its output with the Chocón project (a river hydroelectric power plant now operating) could satisfy a daily demand of 45000KWh. Today, the National Interconnected System (Sistema Interconectado Nacional) allows the combination of outputs of different power plants.

The Valdez Peninsula project would utilize the different tide levels between the Nuevo and San José Gulfs by the construction of a channel through the thin isthmus that separates them. The location is not too far from the current network of the National Interconected System. Moreover, a few kilometers from the site, an important aluminium production factory could benefit from the new power source.

The entire region of the Valdez peninsula is a unique biological and tourist resource, with an important richness in fauna that demands deep ecological study to avoid any damage to important species. The project, therefore, should be studied by an interdisciplinary group taking all these variables into consideration.

In 1984 E. G. Aisiks and T. Zyngierman published a critical analysis of the existing studies and proposals. They said that there were many inland river hydroelectric projects that offer interesting economic possibilities and only need conventional technologies. They considered that all those projects could be operating by the year 2010. They conclude that "the studies carried out at pre-inventory level show that the San José tidal power plant could become attractive once conventional and cheaper hydroelectric resources currently (1984) available are exhausted."[14]

We may say that 15 to 20 years will be needed from the beginning of the studies to the starting of the operation of a tidal energy power plant in the Valdéz Peninsula. The studies therefore should be started now to be able to start production in 2010.

Wave Energy

As we know, the development of technology for wave energy utilization is advancing fast and in many different ways, but it has not yet reached a commercial level (except for very low powers).

International scientific working groups have recently been organized to study small scale ocean energy sources that include, of course, wave energy. Argentina has extended coastal zones, many of them with small energy requirements. It is in Argentina's interest to become involved in these working groups for cooperative research and development.

Coastal and Nearshore Space Utilization

Transportation & Ports

The optimization of the transportation system will require an increase in maritime and fluviomaritime transport and an improvement in its efficiency. Argentina's geography offers a shoreline lacking good sites for the installation of traditional ports: there are no natural deep waters nearshore and little natural protection. The continental shelf is wide and has a smooth slope. The utilization of the ocean space (nearshore and offshore) is now technnically possible and economically feasible. Also, many of the offshore technologies may be used in port operations.

Argentina offers many opportunities to study new conceptions for transport operations: loading and unloading (land to water and water to water), storage and berthing and mooring.

Keeping in mind the characteristics mentioned above, two main priority areas may be defined in relation to water transport: a) the port of Buenos Aires and the complete fluviomaritime system consisting of the Hidrovia Parana-Paraguay/the Plata River/Ocean; and b) alternative low cost port installations, mainly for the Patagonian coast.

The port of Buenos Aires is not a deep water port. It may be reached only by a long channel that requires dredging. The port is surrounded by the 12 millon inhabitants of the city and therefore offers no possibilities for expansion.

Presently the Parana and Paraguay Rivers are under study to transform them into an efficient waterway for fluvial transportation. This would allow enormous regions of Argentina, Brazil, Bolivia and Paraguay — with the participation of Uruguay as well — to have a connection to the Atlantic Ocean. A significant amount of goods would arrive to the River Plate in low draft barges, and many of them would need to be transferred to oceanic vessels.

The hinterland of the Buenos Aires port is very important. And its activity would be signifiantly increased by the cargoes coming down through the Hidrovia. It is important to relate conveniently the inland waterway transportation system to overseas maritime transport, notwithstanding the important current port activities of Rosario and Buenos Aires.

A preliminary project for a deep waters port (1971) analyzed, among other alternatives, an island port solution. Banco Rouen on the Estuary of the River Plate was chosen as the site, in an attempt to use the coastal ocean space. In this case, the River Plate may be considered as an ocean area, with many advantages such as low salinity, shallow waters (less than 30 m = 90 feet) and small waves.

Airports

The city of Buenos Aires has two airports: Ezeiza International Airport and Jorge Newbery Airport (Aeroparque) for domestic flights. Both have limitations that must be solved.

Today, the problems of ports and airports can be reevaluated, taking into consideration the possibilities that have arisen because of recent offshore technologies. The notion that a port or an airport should be placed on land is nowadays only a prejudice. The use of ocean space can greatly promote the search for efficient solutions to maritime and air transportation problems.

There are, of course, many other uses of the quasi-oceanic space of the River Plate estuary besides that of transport systems. These should all be taken into account since they make manifest interesting possibilities in the multiple integration of ocean space.

In the remaining Argentine ports, particularly those of Patagonia, new technology as well as ad hoc technology that could be developed to deal with specific cases, could decrease the cost of construction and of the functioning of airports. This will contribute to the optimal use of a potential transport system covering great extensions of slightly populated territories.

Ocean Science & Technology and Economic Development

All of these areas aim at developing the economy. Today's economic development is understood as "development by means of science." The case of economic development through exploitation and use of the ocean space is the example that best shows the essential participation of science and tecnology in economic and social development. Keeping these considerations in mind the necessity for adequate research and development becomes evident, both in oceanography as well as in ocean engineering (in basic engineering areas and in technologies oriented to ocean technological development).

Human Resources

For the rational and intense use of the sea and its resources a basic priority is the development of human resources, with a strong emphasis on scientific formation. The integration of researchers in the different fields of oceanography and ocean engineering must be achieved. This group of researchers must cover the total scientific spectrum for both sciences and reinforce research and development in the technological areas. It is necessary to train engineers in professional activities concerned with oceanic undertakings, their design, construction, operation, maintenance and dissasembling.

It is necessary to prepare a major part of the country's engineers to work in some oceanic enterprises by integrating interdisciplinary teams of scientists and professionals. Research and development centers in ocean engineering will play an important role in achieving both goals.

It is important to synchronize the formation of highly specialized scientists and professionals with the concrete development of economic programs and specific projects of production and construction. The failure to achieve this synchronization between the formation of specialists and the concrete advancement of specific engineering projects may result in the emigration of scientists and professionals.

SUMMARY AND CONCLUSIONS

Oceanography and ocean engineering complete the process from research to action in ocean space. Therefore, both represent a fundamental progress towards the fulfillment of socioeconomical objectives.

A national oceanic program must be based on the geography and resources of the country; thus among the enormous variety of ocean resources we have pointed out some priorities for Argentina. One of our basic priorities is the the formation of human resources. Post-graduate courses and R&D programs are of great importance. Argentina must take advantage of recent technological developments to stimulate the growth of marine transportation, emphasizing new solutions to port operations.

Since we aim at an overall harmonic development, we should widen the country's possibilities though international cooperation and the transfer of technology. In that way, the necessary technological innovations would be gathered through new developments (local or by cooperation) and through technology transfer.

Cooperation between complementary coutries and among neighboring countries, as well as regional cooperation should be specially stimulated. Given the particular circumstances that characterize present-day Argentina, and in view of achieving social, economic and academic progress, it is clear that we can and must respond quickly to the challenge and the promise of the exploitation and the use of our ocean space. Our national oceanic program must be developed and sustained. We should take great care to include in it both research and development in order to further our knowledge of the ocean, improving our professional action in that medium in view of productive achievements. The huge economic potential now within reach thanks to recent oceanic technological development must be fully applied.

ACKNOWLEDGMENTS

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3

A Strategic Concept for the Development of Coastal Space Utilization Technology in Japan for the 21st Century

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ABSTRACT

This paper introduces the various aspects of coastal space utilization in Japan, and discusses how and in which direction the development of Japan's coastal utilization technology should be pursued. In addition, it indicates the following three major considerations to be taken for the effective promotion of technological development.

1) It is necessary to set up the goals of technological development for coastal space utilization responding to changes in socioeconomic trends in the future, and approach the task of attaining them.
2) The public, academic and private sectors should be engaged positively and/or jointly in technological development.
3) It is necessary to employ measures for making active use of the results of technological development, and for promoting their wide-spread application.

INTRODUCTION

Since the Ports and Harbors Bureau of the Ministry of Transport announced a vision "Toward an Enriched Waterfront" as its long-term port and harbor improvement policy in April 1990, there has been a lively discussion about what form coastal space utilization for the 21st century should take. In the ever-changing socioeconomic environment moving toward the 21st century, coastal space should

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of course be harnessed more extensively and diversely, and to that end it is essential that efforts be focused on the improvement of supporting technology.

This paper introduces the various aspects of Japan's coastal space utilization and then discusses the goals of technological development and promotional measures.

COASTAL SPACE UTILIZATION IN JAPAN

Characteristics of Japanese coastal area

The Japanese archipelago consists of four main islands and about four thousands smaller islands. The entire land area of Japan is only 378,000 km^2, however, the coastline extends over some 34,000 km, and constitutes an important space resource for the country. The coastline length per unit land area is 90.7 x 10^{-3} km/km^2, approximately 5.5 times as great as that of the U.S. (16.5 x 10^{-3} km/km^2).

Of this 34,000 km coastline, 31.7% is comprised of closed bays and inland sea, 15.0% of open bays, and the remaining 53.3% of open sea shore. The economic and social activities of Japan are found primarily in the cities and towns of the coastal area; 60% of Japan's cities having a population over 200,000. Fifty percent of the industrial shipping activity and 60% of the commercial sales of the country are concentrated in these areas. In particular, Tokyo, Ise and Osaka bays and other closed bays and inland seas, blessed with calm natural conditions, have been actively used since ancient times, and serve today as densely populated industrial centers.

Coastal space use

The coastal space supports water-based businesses including maritime transportation and the fishery industry, as well as offering via land reclamation a space for a variety of industrial, urban and recreation activities. At present, there are a total of 1,099 ports, including 133 major ports, and 2,953 fishery harbors in Japan. Ports are closely related with the cities behind them, to ensure the efficient use of their diversified activities. To protect human lives and property from the threat of the nature, disaster-preventive measures have also been taken in waterfront area.

The main coastal space uses in Japan are as follows:

1) Junctions of maritime and land transportation. The primary role of coastal space is to serve as a junction of maritime and land transportation centering upon ports and harbors.

2) Seaside industrial area. Due to its potential to offer extensive reclaimed land and secure low-cost mass transportation by ship, coastal space has made a great contribution as the ideal industrial site for the economic development of Japan.

3) Space for urban activities. Coastal space offers through land reclamation the space required for urban activities. It also serves as a municipal refuse disposal site; such sites are difficult to obtain elsewhere.

4) Space for marine sports and recreation. With its special atmosphere rich in the beauty of nature, coastal space is used for a variety of marine recreation activities and as a space where citizens can be close to the water.

5) As a base for the fishery industry. Japan is richly endowed with fishery resources. To make full use of these resources, fishery industry bases have been established primarily in Japan's approximately 2,900 fishery harbors and other local ports.

Development of coastal space utilization

(1) Deep waters, soft ground and rapid work execution

Japanese coastal space utilization technology has developed at a very fast pace on a large scale over some 120 years since the Meiji Restoration, with emphasis on port and harbor installation, and improvement and development of coastal areas. In this process, developmental efforts have used techniques to meet ever-changing social needs. Some of these techniques, reflecting the geographical, topographical and geological conditions of Japan, are breakwater construction techniques where wave conditions are severe, wharf and revetment construction techniques on soft ground, and rapid and large-scale execution of construction and land reclamation.

Figure 1 shows changes in work dimensions of major breakwaters in Japan. Water depths at which breakwaters are installed have increased from approximately 7 m in the 19th century to approximately 60 m for the breakwater at the Port of Kamaishi today. Design wave heights, as well, have increased from 2 m to 12 m recently, in response to changes in breakwater construction site toward deeper waters.

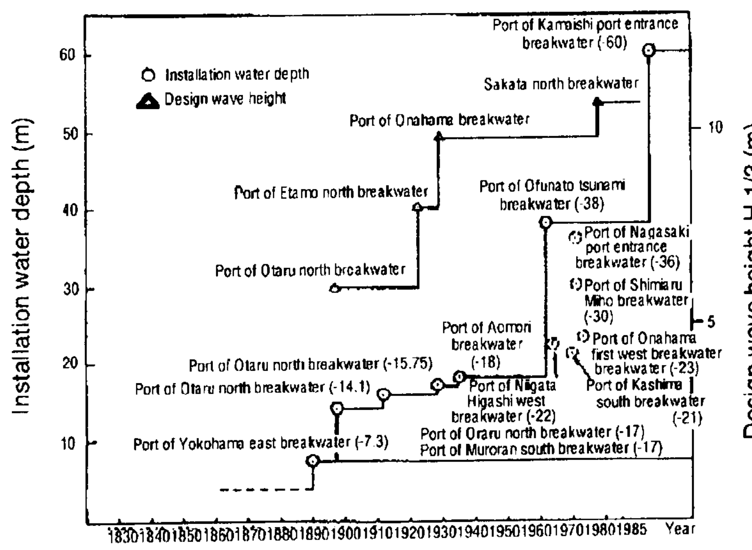

Figure 1. Changes in major breakwater work scale

Figure 2 shows changes in representative soft ground improvement methods. Most of Japan's main ports and harbors are situated inside bays, and most such ports and harbors are located on soft ground. To overcome weak ground conditions, displacement, vertical drain, compacted sand piling, and deep mixing methods have been researched, developed and widely implemented.

(2) Need for water-affinity port and harbor facility

Japanese ports and harbors, highly specialized for distribution and production, are mono-functional, and therefore many of their facilities do not adequately consider human well-being. In recent years, however, Japan's economic power has grown, and accordingly, society has begun to become affluent. Social needs are thus being diversified and sophisticated in every field of human activity. Under such circumstances, now seems to be the time that philosophies in designing port and harbor facilities be reviewed, turning away from the conventional idea that exclusively provides for function and economy, thus rejecting human approaches.

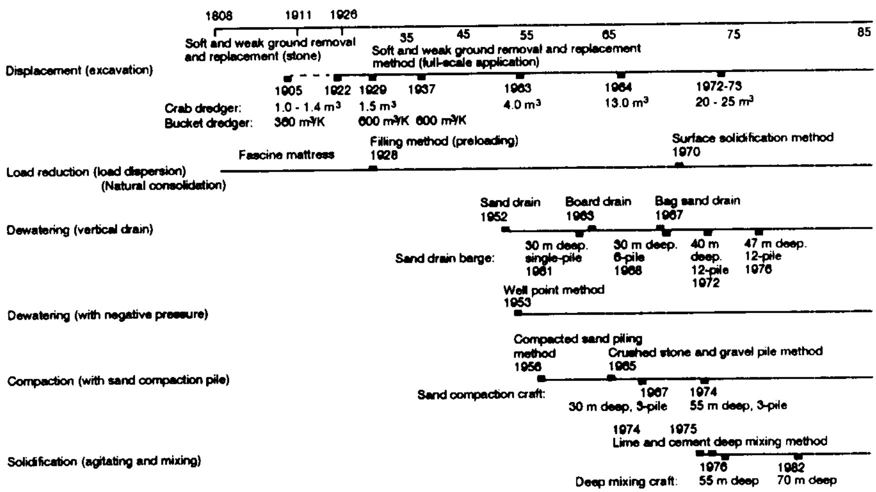

Figure 2. Overcoming soft ground

Ports and harbors for the 21st century

(1) Ports and harbors for the 21st century

With the 21st century approaching and the start of a new era, the Ports and Harbors Bureau of the Ministry of Transport compiled a long-term port and harbor development policy in "The Ports and Harbors for the 21st Century" in April, 1985, recognizing the future direction of socioeconomic changes and the role of ports and harbors.

One of the objectives of the policy is to place emphasis on the people-oriented functions of ports and harbors, which was often overlooked during the period of rapid economic growth, when the distribution and industrial functions were heavily emphasized. This is to achieve harmony and good coordination among these three kinds of functions, which will allow these functions, sophisticated as a whole, to be fully put to use, thus completing "the creation of a comprehensive port and harbor space."

Another objective is "the promotion of networking among ports and harbors" which will allow ports and harbors to strengthen mutual links and operate jointly not only maritime transportation but also information and air and land transportation. Important measures to achieve such objectives are also suggested in "The Ports and Harbors for the 21st Century."

(2) Implementation of the policy

Following "The Ports and Harbors for the 21st Century," the Ports and Harbors Bureau of the Ministry of Transport drew up the 7th Five-Year Port Implementation Plan and the 4th Five-Year Plan for Coastal Protection Works with 1986 as the first year of the plans.

The Ports and Harbors Bureau also established new projects such as the "Port Renaissance 21 Project," which aims at the redevelopment of ports and harbors whose functions no longer meet the demands of the time, and the "Coastal Resort Project," which aims at regional resort development. As for technological development, the "Technical Standards for Port and Harbor Facilities" were revised, and the "Evaluation System for Port and Harbor Technologies of Private Enterprises" and so on were introduced.

"TOWARD AN ENRICHED WATERFRONT" — FOLLOW-UP TO "THE PORTS AND HARBORS FOR THE 21ST CENTURY"

Socioeconomic trends surrounding ports and harbors

(1) Socioeconomic changes

Viewing recent changes in the international socioeconomic environment surrounding ports and harbors, one notices Japan's economic expansion, trade imbalance, and the rapid and sustained appreciation of the value of the yen since September, 1985. This has required that Japan contribute to the international community commensurate with its economic power and to change its economic structure into a more domestic market-oriented one. As well, exchange with thriving, newly industrialized economies in East Asia and Southeast Asian countries is growing vigorously.

Domestically, as social maturation continues, quality is becoming the focus in various aspects in society. People's interests in waterfront areas, marine recreation, cruising on a passenger vessel are growing.

Economic and social activities are expanding beyond the conventional boundaries of their fields, and even beyond the national boundaries.

In terms of regional development, the overconcentration of various functions in Tokyo is continuing, and land prices are skyrocketing in major urban areas. On the other hand, rural areas are having difficulty in achieving economic progress, further expanding the gap between urban and rural areas. Such changes have been taking place at a rate far greater than estimated at the time of the compilation of "The Ports and Harbors for the 21st Century."

(2) Examination of "The Ports and Harbors for the 21st Century"

Amid such socioeconomic changes, continued examination and flexible implementation of measures are indispensable in order for "The Ports and Harbors for the 21st Century" to remain significant as a long-term policy.

At present, five years since it was first drawn up, measures proposed have already begun to take shape. The social and economic changes surrounding ports and harbors have taken place beyond previous expectation, and preparations are being made for new five-year plans which will start in 1991 now that the ongoing five-year plans for port and harbor development and coastal projects have entered their final year. Accordingly, measures proposed in "The Ports and Harbors for the 21st Century" were reexamined while referring to the present situations, making considerations for necessary additions and further emphasis.

Toward an enriched waterfront

As a result, it was decided that it was appropriate to maintain the basic points of "The Ports and Harbors for the 21st Century" as a long-term policy for port and harbor development. Considering the social and economic changes which have taken place since its compilation, however, additional emphasis is necessary on the following points.

(1) Qualitative enhancement of a comprehensive port and harbor space

Since development of "The Ports and Harbors for the 21st Century," the importance of improving distribution, industrial, and people-oriented functions of ports and harbors by implementing various measures intended for the creation of a comprehensive port and harbor has been recognized anew.

It was also recognized that the quality of port and harbor area as easy-to-use and beautiful space, besides having improved functions, was important in trying to respond to people's demand for higher quality against the background of social development. Therefore, it was decided that future endeavors would focus on the improvement of both the functions and the quality of a port and harbor area, thus aiming for an easy-to-use, beautiful port.

(2) Contribution to balanced national development

Networking among ports and harbors has been actively promoted for balanced national development. Meanwhile, passenger maritime transportation has been reevaluated against the backdrop of the growing popularity of cruisers sailing around the country and the world as well as the successive commencement of new operations of high-speed passenger vessels. The volume of import of finished goods has increased rapidly. At the same time, regional problems in urban and rural areas have become serious. These are some of the changes which were not predicted in specific terms when "The Ports and Harbors for the 21st Century" was drawn up. Therefore, it is necessary to further promote the formation of physical distribution and information networks as well as to establish a passenger transport network.

In addition, in order to solve regional problems, infrastructures should be improved to establish integrated local settlement in coastal areas. In rural areas, indigenous and new industries, including the resort industry, will be fostered to realize a lifestyle having more choices. In urban areas, on the other hand, necessary space will be secured to appropriately respond to the housing demand, and infrastructures will be improved to solve traffic problems and to improve the living environment to deal successfully with urban problems.

(3) Measures to realize an enriched waterfront

To carry out such measures smoothly, systems responding to the new demand for qualitative enhancement of ports and harbors will be established, and long-term strategy for technological development of ports and harbors will be created, on which future technological development will be based. Furthermore, long-term prospects for offshore development will be developed, on which future marine utilization will be based.

NEEDS FOR THE DEVELOPMENT OF COASTAL SPACE UTILIZATION

Needs for technological development

With the maturation of society in recent years, increasingly diversified facilities have been developed at coastal areas, thereby diversifying coastal space utilization technology as well. A systematic view of this technology at the present time is shown in Figure 3.

What must be considered in setting up the goals of future technological development are various conditions influencing coastal space utilization technology and changes in the socioeconomic environment, in addition to the coastal space utilization policies as described in the "Toward an Enriched Waterfront" section of this paper.

(1) Port and harbor (coastal) improvement policy responding to socioeconomic changes

- Formation of easy-to-use and beautiful port and harbor space
- Formation of advanced physical distribution space
- Formation of enriched living space
- Improvement of seashore living infrastructures

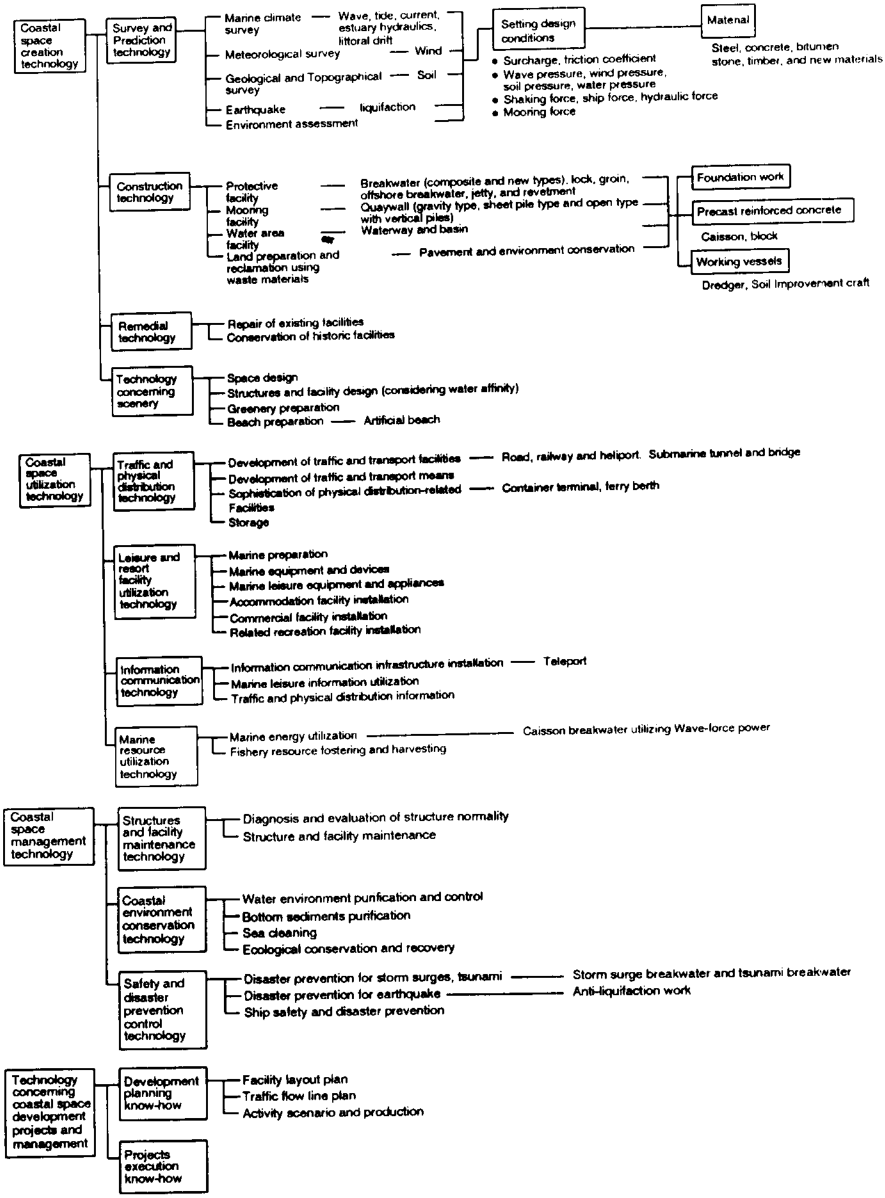

Figure 3. System of coastal space utilization

- Conservation and creation of coastal environment
- Advanced utilization of coastal space
- Creation of an enriched seaside area

(2) Various conditions influencing coastal space utilization technology

- The shortage of labor for port and harbor construction
- Increasingly stringent conditions for work implementation
- Aging of existing facilities
- Advances in technological development in other industrial fields
- Needs for technology to support international cooperation

(3) Changing socioeconomic trends

- Emergence of global environmental issues
- Long-range energy-related problems

The goals of technological development

By taking into account the various conditions influencing the development of coastal utilization technology as shown in the foregoing paragraph, the following goals of future technological development are brought out. Emphasis in technological development must be focused on these goals in the future.

(1) Technological development aimed at an enriched waterfront

- The formation of easy-to-use and beautiful port and harbor space
- Qualitative enhancement of a comprehensive port and harbor space
- The creation of an enriched seaside area

(2) Technological development aimed at the conservation and creation of coastal environment

- The conservation of coastal environment
- The restoration of deteriorated coastal environments
- The creation of a new coastal environment

(3) Technological development to realize long-term prospects for offshore development

(4) Technological development for mechanization and automation

- Labor savings in works
- Higher work efficiency
- The improvement of working environments
- To avoid errors

(5) Technological development for the maintenance, control and rejuvenation of ports and harbors

- Maintenance and control
- Rejuvenation

(6) Technological development to contribute to the international society

- To cope with specific problems in foreign countries
- To cope with problems common to foreign countries

(7) Technological development to cope with global environmental Issue

- To grasp global environmental phenomena
- For coping with global environmental issues

(8) Technological development to cope with long-range energy-related problems

- For energy savings
- For alternative energy sources

(9) Technological development for ports and harbors of the future

- To cope with ultralong-term tasks
- Visionary ports and harbors

STRATEGY FOR PROMOTING TECHNOLOGICAL DEVELOPMENT

To attain the goals of technological development, it is necessary that firm systems be established in which technological development can be pursued more actively than ever.

Solidarity and moderate competition among the public sector (state, public corporations, port/harbor authorities, etc.), the educational institutions (universities) and the private sector (private enterprises)

(1) Moderate competition in technological development

In technological development, it is not always desirable to restrict the development activity of individual organizations within certain narrow areas. Indeed, if two or more organizations are engaged in a similar task at one time, it means duplicate investments and such organizations may even seem not to bring their strong points into full play. But it is advisable for a nation as a whole that various pioneer attempts be made by various organizations, with the result that the development of all technologies indispensable for a nation are being pursued in some forms or other. A moderate competition in such technological development activities will lead to the establishment of diverse technologies capable of meeting diverse needs. To that end, the public sector should provide all necessary information, and more importantly, they should not discourage individual organizations, but encourage them to engage freely in their own task of developing new technologies. Thus far, the public sector has primarily taken the initiative in promoting technological development. In recent years, however, the private sector's technological capabilities have been growing, and this has led to great expectations for private firms' technological development especially in fields where they excel.

(2) Solidarity among organizations engaged in technological development

Due to the characteristics of port and harbor technologies, there are cases, depending on the type of task in technological development, where technological development can be achieved more efficiently and economically through partnership in terms of technical capabilities, labor, information, facilities and funds among organizations sharing one objective with one another than independent approaches by individual organizations.

In such cases, a desirable form of solidarity is as follows:

1) Joint technological development: Conducting more efficient, more advanced technological development through the optimal allotment of work and partnership in cases where two or more organizations having technological capabilities, labor, information, facilities and funds share one objective and are willing to work jointly in technological development

2) Technological development through interchanges: Conducting more efficient, more advanced technological development in cases where two or more organizations having human resources, funds, facilities and information, exchange some of these elements with one another to supplement their weak points (personnel interchange system, assigned research system, utilization of facilities, Japan Comprehensive Building Information Center, the Ministry of Construction)

3) Technological development by associated body: Performing more efficient, more advanced technological development through cooperation with one another by pooling funds and other elements in cases where two or more organizations share one objective but their individual capacities are insufficient for them to undertake technological development independently

Strengthening supporting measures to promote technological development in the private sector.

The public sector will assist the private sector in reducing the latter's burden, while at the same time taking appropriate steps to deal with the private sector's demand for technological development, in cases where the implementation of technological development imposes an excessive economic burden on the private sector due to the specialty of port/harbor technologies.

(1) Funds

Subsidizing and financing for technological development expenditures (Japan Development Bank, the Ship & Ocean Foundation)

(2) Taxation system

Preferential treatment in taxation (tax credit system for additional testing and research expenditures)

(3) Intercession

Intercession for facilities (offshore practical test yard provision system, lending of experimental facilities) and partnership stated above, in addition to subsidizing and financing

(4) Grasping the private sector's requests and coping with them

Grasping and coping with the private sector's requests for technological development and related countermeasures.

Promotion of exchange with different fields, and positive introduction and utilization of technological development achievements by different fields.

Both the technologies developed in different fields and those developed in the port/harbor field should be introduced and utilized for promoting diverse technological development to cope with diverse needs.

(1) Exchange with different fields

(2) Positive introduction and utilization of technological development achievements by different fields

Establishment of an information collection system to grasp the present situation of technologies in fields other than ports and harbors, and utilization of conventional systems; establishment of a clear distinction between technological developments to be conducted in the port/harbor field and those to be conducted using achievements by different fields, along with establishment of the system to evaluate and examine introduction potentials and measures of technologies of different fields into the port/harbor field

(3) Request to different fields for technological development

Positive PR activities on technologies required in port/harbor field to different fields

Securing human resources, and promotion of their development

Human resources should be secured and at the same time fostered to transmit technology and maintain its level.

(1) Securing human resources

Enlightenment through positive PR approaches, improvement of treatment and work environment

(2) Fostering of human resources

Improvement of training system, optimum allocation of human resources for technological development, assessment (improvement of treatment), implementation of measures to heighten their technological development incentives (improvement of work environment, reward system, extensive PR activities of technological development organizations, development of future technologies)

Organic control of information regarding ports and harbors, and improvement of its application system

Positive inducement to technological development by technological development organizations will be promoted by facilitating acquisition of information regarding ports and harbors, and at the same time their technological development incentives will be heightened.

(1) Announcement of public information regarding ports and harbors

Collection and announcement of public information regarding ports and harbors (policies for port/harbor improvement, investment amount, technological development themes to be required, technical information and others)

(2) Organic control of information

Improvement of port/harbor information collection and control system (software and hardware)

(3) Improvement of information application system

Improvement of environment and system that can freely utilize port/harbor information.

Organizational tackling with technology transmission

Organizational coping with technology transmission and establishment of personnel system for technology transmission are necessary to maintain the technical capability.

(1) Technical information transmission

Establishment of technical information collection and control system on a sustained basis, and improvement of related facilities.

(2) Technology transmission via personnel

Improvement of training system, and establishment of personnel systems and organizations for obtaining and transmitting technologies in routine work.

Positive PR activities on ports/harbors and their technologies

Positive PR activities should be implemented on ports/harbors and their technologies for appropriate induction for technological development in the port/harbor and related fields, and for securing human resources and heightening their technological development incentives.

(1) Strategies for PR activities

Devising of PR strategies by taking into account the social recognition of port/harbor technologies in the selection of items, objects and media in implementing PR activities and in the evaluation of effects of PR activities.

(2) Utilization of experts of PR activities

Utilization of experts from the initial implementation stage of PR activities.

Improvement of evaluation system for technological development

Evaluation in each technological development stage (theme selection, mid-course progress and achievements) will be made for heightening technological development incentives and promoting effective technological development. And a system will be established which can embody in technological development the results obtained by appropriately evaluating the reasons in the case of failure, or the achievements in the case of success.

(1) Evaluation in the course of technological development

Establishment of the system to examine the subsequent measures by appropriately evaluating the importance and urgency of technological development themes and the mid-course progress.

(2) Evaluation and examination of technological development achievements

Establishment of the system to fairly evaluate technological development achievements (perfected technologies) — the evaluation system for the private sector's technologies; and establishment of the system to fairly evaluate and examine technological development achievements (reasons and measures for improvement in the case of failure, and perfectness and future directions in the case of success).

(3) Improvement for software technology evaluation

Heightening recognition of software technology (allocation of funds to software technologies, and their appropriate reflection on fund estimation).

Positive utilization and diffusion of technological development achievements

Technological development achievements will be utilized and diffused positively and practically so as to heighten technological development incentives.

(1) Utilization and diffusion of technological development achievements

Improvement and preparation of standards and systems for smooth utilization and diffusion of technological development achievements in their practical application (application of appropriate estimation and execution control standards, abolishment of indiscriminate application of standards, examination of contract system, value engineering system, pilot works to use new technologies).

(2) Heightening technological development incentives

Priority application right for new technologies, reward system.

Securing and effective use of technological development funds

Funds required will be secured for developing necessary technologies.

(1) Securing funds

Foundation of the new financing system for technological development, and effective utilization of funds already secured.

(2) Appropriate allocation of funds

Appropriate allocation of funds, based on the evaluation system stated above (priority allocation, sustained allocation, and discontinuance of allocation).

Tackling technological development for contributing to the global society

Japanese technologies will be utilized and technological development will be further promoted to contribute to the global society.

(1) International exchange

Participation in and holding of international conferences.

(2) Technology transfer and technical cooperation

Promotion of technology transfer to developing nations and technical cooperation with advanced nations (English-version publication of Japanese technical standards and their announcement overseas, joint technological development, technological development matching overseas situations).

CONCLUSION

For the development of coastal space utilization technology, its goals and promotional measures have been discussed. The conclusion can be summarized as follows:

1) It is necessary to set up the goals of technological development for coastal space utilization responding to changes in socioeconomic trends in the future, and approach the task of attaining them.

2) The public, academic and private sectors should be engaged positively and/or jointly in technological development.

3) It is necessary to employ measures for allowing active use of the results of technological development, and for promoting their wide-spread applications.

It should be noted that neither the goals of technological development nor the strategy for promoting technological development is authorized by the Ministry of Transport. However, the Ministry of Transport is now moving to work out a "Long-term Strategy for Technological Development for Ports and Harbors" to be completed in March 1992, for which discussion is underway about the goals of technological development and the strategy for promoting technological development as described in this paper.

4

Canadian Policies and Programs for Coastal Ocean Space Utilization

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INTRODUCTION

Canada's motto "From Sea unto Sea" was aptly chosen, for Canada is a country that not only spans a continent from the Atlantic to the Pacific but also reaches north to the Arctic Ocean. Canada has the longest coastline in the world — 150,000 miles, of which two-thirds is in the Arctic. With the signing of the Law of the Sea Treaty in 1982, Canada claims the world's second largest continental shelf — 2.5 million square miles — adding almost 60 percent to an already vast land territory.

Canada's coastal ocean space is also rich in resources. The fishery contributes to income and employment on three coasts, particularly the Atlantic, and offshore hydrocarbons are poised for development off Nova Scotia and Newfoundland. Oceanic industries and services provide employment in numerous high technology companies and marine shipping is vital to a number of coastal ports, particularly Vancouver, Montreal, Quebec City, and Halifax. Shipbuilding, especially for naval defense contributes to Saint John, New Brunswick, and recreational uses of the oceans abound in British Columbia, Quebec and the Atlantic Provinces. The use of Canada's ocean resources and ocean space accounts for $6 billion each year and provides approximately 165,000 jobs.

In recognition of the increasing importance of the oceans, the federal Department of Fisheries and Oceans announced in 1987 an Oceans Policy for Canada. This document cited three reasons why a new oceans policy was necessary, listed four goals, and proposed an action plan comprising six steps to be implemented through a number of new and existing programs. Has this policy statement had a major influence on the utilization of Canada's coastal oceans?

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More generally, what have been some of the major economic activities in Canadian ocean space and what has been the policy framework within which these developments have taken place? Put another way, does Canada have an effective national strategy for Canadian ocean management and development? A map of Canada's 200 mile zone and continental shelf is shown in Figure 1.

OCEANS POLICY FOR CANADA: 1987

In 1973 the then Minister of State for Science and Technology announced a new oceans policy for Canada. The stated aim was to improve significantly Canadian scientific and technological capacity in the oceans and to foster the development of Canadian ocean industry. (See Appendix 1.)

This policy statement was made at a time of increasing oil and gas exploration in the Canadian offshore and during a period when there was a strongly felt need by many Canadians to demonstrate forcefully independent actions in the economic, political and social aspects of national life. This sentiment was demonstrated clearly in federal government policies toward the Arctic, a geographic area and concept of central importance to Canadian nationalism. One such response by then Prime Minister Pierre Elliott Trudeau, was to create Panarctic Oils to explore for oil and gas in the high Arctic.

The passage of the S.S. MANHATTAN through Canadian Arctic waters in 1969 exacerbated these national feelings. In response, Canada proclaimed in 1972 the Arctic Waters Pollution Prevention Act, which created a Pollution Prevention Zone extending 100 nautical miles outward from the Canadian Arctic archipelago. Ice zones were created and shipping in the area was required to conform to Canadian standards when entering the area and the specific zones. In addition, a 12 mile territorial sea was declared in 1972 which reached across the Northwest Passage.

Exploration for offshore oil and gas was also gaining momentum on the Scotian Shelf off Nova Scotia, the Labrador Shelf, Hudson's Bay, Beaufort Sea and the Pacific Coast, almost all by foreign-owned companies, especially American. The OPEC induced oil crises of 1974 and 1979 further added to Canadian concerns.

In 1985 the U.S. ice-breaker POLAR SEA traversed the Arctic ocean from east to west through what was seen by Canadians as territorial sea and by the Americans as an international strait, the Northwest Passage. Canadian concerns about national sovereignty in the Arctic were heightened once more. The next year, the Prime Minister asked the Minister of Fisheries and Oceans to strengthen the "oceans" component of his department's mandate. A national planning conference in 1986 was followed one year later by the declaration by the Minister of an "Oceans Policy for Canada to Meet the Challenges and Opportunities on the Oceans Frontier." The goals of the policy, as in 1973, centre upon improved Canadian industrial, scientific and technological competence in the oceans.

Additional goals are improved ocean resource-management, environmental protection and assertion of Canadian sovereignty. (See Appendix 2).

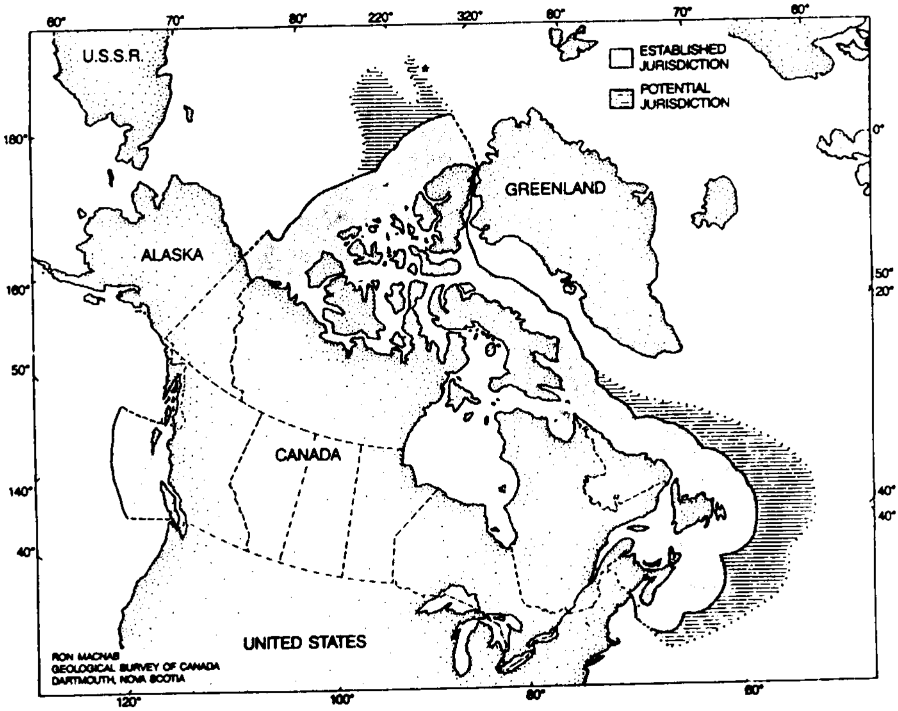

Figure 1.Canada's 200 Mile Zone and Continental Shelf.
Source: Canada. Dept. of Fisheries and Oceans. 1987. Oceans Policy for Canada, Ottawa, p. 1.

A number of specific initiatives have resulted from this policy. A National Marine Council to advise the Minister has been formed, ocean mapping has continued apace, an Oceans Technology Promotion Office has been created, and a federal government discussion paper has been prepared to consider a Canada Oceans Act to consolidate and clarify the legal regime in the offshore. This might well include the declaration of a 200 mile Exclusive Economic Zone, to coincide with the 200-mile fishing zone Canada declared in 1977. A 12 mile contiguous zone is also being considered. A five year Marine Science Plan has been approved by the Interdepartmental Committee on Oceans and an Arctic Marine Conservation Strategy has been brought forward for discussion. (See Appendix 3.)

One means of evaluating this expression of a Canadian oceans strategy is to describe some of the recent developments in Canadian ocean space and to consider subsequently the extent to which the "Oceans Policy for Canada" has shaped these activities.

FISHERIES

While accounting for only a fraction of Canada's total economic output, the fisheries have a strong regional impact, especially in Atlantic Canada. In Nova Scotia, for example, 16 percent of the value of provincial output is accounted for by the fishing industry and for the 500,000 residents of Newfoundland the number is even higher at 20 percent. More importantly, it has been estimated that 1500 communities in Canada are solely or principally dependent on fisheries harvesting and processing and most of these are in Atlantic Canada. On the Pacific coast the fishery is of relatively less importance accounting for 6 percent of the gross provincial product of British Columbia. (See Appendices 4 to 7).

It is not surprising then that one of the policies guiding the fishery has been to maintain maximum employment in the industry, while seeking to ensure adequate returns for the industry overall. In recent years, the Atlantic fishery has been plagued by low fish prices and reduced catches of ground fish, especially the northern cod stocks off Newfoundland and Labrador. Fish plants have been closed, quotas of ground fish have been reduced and losses have been incurred by many of the companies in the industry. Overfishing, both within and outside the Canadian 200 mile zone, has been a major factor.

Outside the Canadian zone, the North Atlantic Fisheries Organization (NAFO) sets quotas for the area beyond the 200 mile limit that includes the seaward extension of the continental shelf known as the "nose" and "tail" of the Grand Banks, along with the Flemish Cap. Canada has repeatedly maintained that these quotas are excessive, especially on the part of the European Community (EC) and as an expression of concern has appointed Canada's principal ambassador to the Law of the Sea, J. Alan Beesley, as special ambassador of Marine Conservation to the European Community on this issue. More recently, NAFO quotas have been reduced, but not yet to the level sought by the Canadians.

Within the 200 mile limit, a degree of overfishing appears to be encouraged by the quota system itself. Given the difficulty of monitoring hundreds of landing sites in the Atlantic fishery, along with questions of by-catch, the general quota system is being increasingly supplemented with individual boat quotas, mesh size increases and limitations on the number of nets that can be carried on any given trip. In addition, mandatory dockside weigh-in is soon to become a requirement, as are stricter penalties for fisheries infractions. Foreign fleets operating within the 200 mile limit are closely monitored by on-board Canadian observers. On the Pacific Coast, the industry is generally considered to be more healthy and profitable than its Atlantic counterpart.

OIL AND GAS

Canada's first commercial offshore oil and gas project is expected to come on stream in 1992. The Cohassit/Panuke development on the Scotian Shelf is scheduled to produce for export crude oil from two wells near Sable Island. Offshore oil and gas in Canada is shaped by two principal government policies or objectives: first, maximum possible industrial benefits for the coastal provinces and Canada, and secondly, thorough screening for environmental impacts.

All environmental requirements for the project have been met. Few obstacles were encountered as the crude is particularly "light" and "sweet" and would cause only minimal damage to the coast and fishery in the event of a spill or blow out. Further, the well sites are in an area of comparatively little fishing activity. Cohasset/Panuke is a very small field, only one-tenth the size of the Hibernia field of Newfoundland, and is being financed without any direct assistance from the federal or provincial governments. This $214 million project is expected to yield significant onshore benefits for Nova Scotian and Canadian companies worth $161 million, or 47 percent of the total expenditures. Royalties and provincial tax revenues will accrue to the Province as if the project were on land; federal corporate income taxes will be paid to Ottawa. (See Appendix 8)

In contrast, the development which was imminent in the mid-1980s, the Venture Gas field, is not being considered actively at this time because of low gas prices.

The $5 billion Hibernia offshore oil project, 190 miles southeast of Newfoundland, has also received regulatory and environmental approval. With direct and indirect financial assistance from the federal government of up to $2.78 billlion, the Hibernia project is expected to begin oil production in 1996 and to have a producing life of 18 years. A particularly noteworthy feature of this project is the gravity based production system (GBS) that will anchor the platform to the ocean floor in a manner sufficient to withstand the massive forces generated if it were to be struck by an iceberg. The risk of iceberg scour along the ocean floor has also been factored into the design equation. At least one of the five large modules comprising the topside structure will be built in Newfoundland, as will the massive GBS structure. (See Appendix 9)

The operating environment for Hibernia is extremely hostile. The force of North Atlantic storms was demonstrated with particular tragedy when in 1982 the OCEAN RANGER drilling rig capsized on the Grand Banks and sank with the loss of all aboard, mostly Newfoundlanders. At that time, the OCEAN RANGER was the largest semi-submersible in the world and one of the most sophisticated. More recently, the ROWAN GORILLA I, the world's largest jack-up rig, sank while being towed across the North Atlantic in winter. Fortunately, in this case there was no loss of life, but it is nonetheless a reminder of the dangers of working in these waters. With icebergs also posing a major threat, it is not surprising that safety is uppermost in the minds of Newfoundlanders.

The regulatory authorities for both the Nova Scotia and Newfoundland offshore areas comprise joint federal-provincial boards made up of equal representation from both governments, with a neutral chairperson.

On the East coast, two areas are off-limits for offshore oil and gas. First, George's Bank is under a moratorium until after the year 2000 and possibly longer in recognition of the sensitive marine environment and high productivity of the fishery in the area. The fishing industry had launched a very strong campaign against drilling, especially as regards the program planned by Texaco Canada Limited. Secondly, the small French owned islands of St. Pierre and Miquelon off the south coast of Newfoundland have occasioned a Canada-France maritime boundary dispute. Until the demarcation line is drawn — expected in early 1992 — oil and gas exploration in the disputed zone is not permitted. (See Appendix 10)

Offshore in the Mackenzie Delta/Beaufort Sea Region, a total of 87 wells have been drilled, yielding encouraging results through 27 significant discoveries — 6 oil, 12 oil and gas, and 9 gas. Exploration and delineation wells are being drilled from specially designed platforms. The technology that is being used includes sprayed ice islands made of thickened ice pods resting on the sea floor; man-made islands; a conical drilling unit named "Kalluk;" a caisson-retained island ("Molikpaq") and ice reinforced drill ships. Specifically designed ice breakers and supply boats are also in use.[8]

The regulatory process in the Canadian Beaufort Sea includes assessment by an Environmental Impact Review Board partially selected by the aboriginal inhabitants, the Inuvialuit. In July 1990, the Board recommended against the drilling program proposed by Gulf Canada on the grounds that the environmental risks were too great. The proposed drilling program is now being re-evaluated.

For other frontier areas in the North, the regulatory authority had been the Canadian Oil and Gas Lands Administration (COGLA). In February, 1991, however, COGLA was eliminated and its functions distributed among the National Energy Board, the Department of Energy, Mines and Resources, and the Department of Indian Affairs and Northern Development.

In the Arctic Islands, Panarctic is making seasonal shipments of oil from its Bent Horn field on Cameron Island. The crude oil is carried out by the Canadian ice-strengthened tanker and cargo ship, M.V. ARCTIC.

On the Pacific coast, there is a prohibition on offshore oil and gas exploration activity. The Province of British Columbia and the federal government have concluded that, while this area holds significant oil and gas potential, drilling poses unacceptable risks to the environment.

MARINE SHIPPING

Heightened concern for the environment is reflected in the recommendations of the Public Review Panel on Tanker Safety and Marine Spills Response Capability. In their final report, the Panel recommends that as much as two-thirds of the $1.5 billion cost of implementing its 107 recommendations be raised by a $2/tonne levy on all oil and oil products transported in Canadian waters. Double-bottomed vessels would pay only one half this amount while double-hulled vessels would pay no levy at all. In addition, the Panel recommends that the entire Canadian fleet of tanker and tank barges be double-hulled within seven years, and that all tankers and tank barges entering Canadian waters be double-hulled within ten years. The report also advised strongly against the transportation of oil out of the Arctic by tanker and recommended instead that pipelines be used wherever possible. (See Appendix 11)

SHIPBUILDING AND REPAIR

The Canadian shipbuilding and ship repair industry faces weak domestic demand, along with strong competition from abroad. The exception is the Saint John Shipbuilding Limited Company that is the prime contractor for the $10 billion project to construct 12 patrol frigates by the year 1996. The first three ships are to be built at the Saint John yard, the next three in Quebec City by the MIL Group of Montreal, and the final set of six in Saint John. Designed in Canada and the United States, the ships are described as "super sophisticated" and the Saint John yard, as a result of the contract, has acquired valuable new skills, personnel, and facilities.

A second naval defense acquisition of 12 Maritime Coastal Defense Vessels for $450 million should also provide some needed work for Canadian yards. Additional requirements by the Coast Guard, Fisheries and Oceans, and Public Works could add to this demand.

OCEANIC MANUFACTURING AND SERVICES

A number of Canadian companies and individuals provide oceanic products and services for use in the Canadian offshore and abroad. The industry seems especially strong on the West coast but with the development of the Hibernia field, along with Cohasset/Panuke, industry on the East coast should be bolstered. The level of demand by governments for oceanographic services for use in marine science and defense also affects the industry. (See Appendix 12)

Many have expressed the wish to see a greater transfer of technology out of marine scientific laboratories and into commercial products. This process may well be facilitated if a proposal made in 1988 to the Department of Fisheries and Oceans and presently under consideration comes to fruition. This would see Canada's marine laboratories complemented by a separate unit created especially to foster the transfer process.

The DOLPHIN (Deep Ocean Logging Platform) project provides a particularly good example of cooperation between government and industry. The DOLPHIN, complete with hydrographic instrumentation and navigation, was built by International Submarine Engineering Ltd. in British Columbia. The first four vessels were developed with the support of a $3.6 million investment by the Government of Canada. Several additional units have been constructed, some for use by the U.S. Navy.

There has been a continuous effort to develop ocean industry in Nova Scotia, notably in the Halifax-Dartmouth area. The Nova Scotia Research Foundation Corporation (NSRFC), the provincially-owned research establishment, has had ocean industry as a focus for almost 20 years. A number of products have been developed and transferred out to local and regional companies for manufacture. A good example of this process is the local production of a product developed by NSRFC, the electrical slip-ring which allows a number of electrical contacts to be maintained through a rotating motion. A federal-provincial ocean industries sub-agreement signed in the early 1980s contributed to the construction of an ocean industries industrial park in Dartmouth.

Competitiveness in high-technology products and services for the oceans, as in any industry, requires strong technological competence, reliable low-cost inputs and a network of competent supporting industries. The demand for oceanic products and services is conditioned by the level of domestic ocean activity in the private and public sectors, their policies as regards servicing from outside suppliers as well as the existence or otherwise of public policies that favor local regional or national suppliers. The "contracting out" policies of the research laboratories are directly relevant here as are the "benefits plans" included in the offshore oil projects.

TIDAL POWER, THE FIXED LINK, AND THE TITANIC

With some of the highest tides in the world, the Bay of Fundy has been a candidate for development of tidal power. The first serious study in Canada of this possibility was carried out in 1944, and later — in 1956 and 1961 — joint Canada-U.S. studies were undertaken. Both countries continued through the 1970s and later to evaluate this potential power source.

Two sites have received particular attention: a $3.4 billion 1400 megawatt site joining Nova Scotia and New Brunswick on the Cumberland Basin, and across the Minas Basin, a larger 5000 megawatt project involving a barrage, 8 km. long. Nova Scotia is the site of the first tidal power plant in North America. Constructed in the early 1980s at the mouth of the Annapolis River at a cost of $52 million, it provides 20 megawatts. While this pilot project is operating successfully, no new projects are planned. Major tidal projects are expected to generate serious environmental impacts: fish kills would be excessive and simulation models predict that for the larger site, tidal ranges could be increased from 3 to 5 inches as far south as Boston. There are technical problems surrounding sedimentation, and the electricity produced would be high cost. In addition, complex "re-timing" negotiations would have to be entered into with New Brunswick, New England, and Quebec. Authorities in that province would likely see tidal power as direct competition for the second phase of their massive James Bay hydro-electric project.

A large project that is being actively considered is a tunnel and bridge to connect the Province of Prince Edward Island to the Canadian mainland. Here too, the expected environmental impacts and the high costs of construction have delayed the approval process.

On April 10, 1912, the TITANIC, the largest and most luxurious ship of her day, departed Southampton, England for New York on her maiden voyage. One hundred and ten hours later, approximately 1500 lives had been lost and the ship lay broken on the ocean floor under 12,540 feet of water. The TITANIC was found on September 1, 1985 and by all definitions of the continental margin (i.e. Article 76 of the 1982 U.N. Convention of the Law of the Sea) the R.M.S. TITANIC lies on the Canadian "judicial" shelf. Accordingly, Canada can be seen as the nation with jurisdiction over the site. The United States has passed the R.M.S. TITANIC Maritime Memorial Act of 1986, encouraging international action to designate the TITANIC as an international maritime memorial. What political or legal position, if any, should Canada take regarding salvage rights or historical preservation?[81]

EVALUATION OF CANADA'S OCEANS POLICY

Canada's 1987 ocean policy statement has given encouragement to those Canadians supporting the concept of a "Three Oceans—One Nation" policy. Despite this, however, it is difficult in the Canadian political and administrative system to separate the oceans component from all other activities. The administrative aspects of the government are for the most part not oriented toward coastal ocean space and with few exceptions, activities in the coastal zone are extensions of land based operations. For example, the Department of Transport manages ocean shipping while Energy, Mines, and Resources extended its influence into the offshore through COGLA. Apart from the Maritime Command of the Department of National Defense and the Coast Guard, the Department of Fisheries and Oceans is the only department with a largely marine focus, and that too is shaped by the compelling commercial and political questions that continue to dominate the fishery. For the most part, the "oceans" mandate of the Department is accorded insufficient attention. Appendix 13 lists legislation related to the offshore along with those departments having some interest in it.

In 1971, the Science Council of Canada recommended the creation of a NASA-like agency to develop the oceans — a Canadian oceans development corporation. This recommendation was not accepted. Later, in the 1980s, however, Canada did create a national space agency based in Montreal.

As thirteen federal departments and agencies have interests in the oceans, the Department of Fisheries and Oceans — as the sole author of the Oceans Policy — may have difficulty implementing the policy. The Multi-year Marine Science Plan is perhaps an exception, as it was prepared by the Interdepartmental Committee on the Oceans, and it has broadly based support within government.

One test of the 1987 policy is to consider the extent to which the proposed actions identified in the policy have been implemented. While a definitive judgement along these lines is difficult, the following tally may prove instructive.

• National Marine Council: this has been formed but appears not to have funds of its own to commission studies and carry out research. Also, does the Council meet regularly and does it have the ear of the Minister?

• Canada Oceans Act: this is under study but will the proposed act be substantive and clarify legal relationships between the federal government and the provinces?

• Ocean Technology Promotions Office: this has been created but should it in fact have been a priority area? In any event, have sufficient financial and human resources been allocated to make it effective?

• While an international marine science organization for the North Pacific is under discussion, and Canada has co-sponsored a U.N. resolution regarding drift net fishing, questions in other areas remain. Have sufficient resources been devoted to Canada's oceanic industries and has mapping of the continental shelf proceeded at the pace anticipated?

• Does the important funding agency for science in Canada, the National Science and Engineering Research Council (NSERC) encourage oceans as a research focus? Does the Department of Fisheries and Oceans allocate sufficient funds to the "oceans" as opposed to the "fisheries" interests of that department?

In contrast to the narrowly-based 1987 Oceans Policy stands the 1990 announcement of the federal government's Green Plan. Backed by $3 billion in funding over four years, this lengthy and detailed document spells out the government's commitment to move toward sustainable development in Canada. A number of provisions relate to the coastal oceans including control of land-based pollution, fisheries management, drift net fishing and ocean dumping.

The Plan also envisages the creation by 1996 of three new marine parks, including South Moresby in the Queen Charlotte Islands, British Columbia and the Saquenay River in Quebec. Additional marine parks are promised by the year 2000. (See Appendix 14)

In a different vein, it should be noted that the 1987 Ocean Policy focusses on Canadian coastal ocean space and makes no reference to official development assistance and the role that Canadian oceans expertise might play in assisting Third World countries to develop and manage their own coastal areas. Nevertheless, the Canadian International Development Agency (CIDA) and the International Development Research Council (IDRC) have had for some time significant marine components in their programs, especially fisheries. In addition, a unique Canadian crown corporation, the International Centre for Ocean Development (ICOD) has been created expressly for this purpose.

Since its founding three years after UNCLOS III, ICOD has undertaken projects in seven major categories: integrated oceans management; fisheries management and development; mariculture; coastal development and management; non-living resource management; maritime transport and ports; and marine environmental conservation.

In order to apply most effectively the efforts of its 60 employees and its annual budget of $13 million, ICOD has chosen to focus on four specific geographic regions: the Caribbean basin, the South Pacific, the South and West Indian Ocean, and West Africa. More recently, the newly independent country of Namibia, has sought ICOD's assistance with its maritime boundary delimitations and fisheries management policies and practices.

In Canada, ICOD supports graduate programs in marine affairs at Dalhousie University in Halifax and the University of Quebec at Rimouski. Direct funding is provided ($1.7 million over 6 years), as are twenty scholarships per year for candidates from eligible countries to attend these programs. In Sweden, ICOD is funding a Professorship in Marine Affairs at the World Maritime University (WMU), an international higher education institution within the United Nations system. ICOD also funds a chair at the University of the South Pacific.

For the major ocean activities of the fishery, offshore oil and gas, marine shipping, shipbuilding and repair, as well as oceanic manufacturing and services, the 1987 Oceans Policy seems to have had little effect. For example, the fishery is largely shaped by such factors as the Canadian social policy of maintaining maximum employment in the industry, the estimation and availability of resources, technological change, bilateral fishery agreements, and international trade policies. Offshore oil and gas activity is conditioned by global events that determine the world price of oil, geological constraints, technological advancements, environmental considerations, government monetary and fiscal policies, and so on.

CONCLUSION

The announcement in 1987 of an Oceans Policy for Canada was welcomed by many as a restatement of national commitment to managing and developing in a responsible manner Canada's coastal ocean space. The policy in itself was an achievement, providing yet another building block in Canada's development of a comprehensive policy toward the oceans.

The 1987 statement, however, was weakened at the outset by the fact that it was the product of only the Department of Fisheries and Oceans — albeit the principal oceans arm of the Canadian government — but other federal government departments also have clearly identified marine interests. In addition, from the vantage point of 1991, it appears that more remains to be done to implement some of the specific actions referred to in the strategy document.

Nonetheless, there is reason to hope that Canada's ocean space will be more effectively utilized in the future. Internationally, a signed Law of the Sea Treaty should allow better regulation and organization of ocean uses, and nationally, concepts and mechanisms of coastal zone management are being increasingly developed and refined. Economic growth and a steadily increasing population in Canada and worldwide should heighten demand for renewable and non-renewable resources of the oceans as well as recreational uses of the sea. New technologies should also enhance the capacity of the oceans to contribute to the national goals of regional prosperity, security, and a healthy bio-physical environment. Moreover, mounting pressures on the world's ecosystems will demand an increased understanding of all aspects of the oceans, especially as they are affected by the global climate change that many see as inevitable.

Canadians need to turn their faces to the sea and shoulder their full responsibility as stewards of a vast, unique and fragile portion of the world's ocean space.

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APPENDICES

Appendix 1: Canada's National Oceans Policy 1973

In 1973, when offshore oil and gas activity off the east coast of Canada was at its peak, Canada's first Oceans Policy was announced. The objectives of this policy were fourfold:

- to stimulate development and effective participation of Canadian industry in the offshore and see that Canada controls the essential industrial and technological ingredients to exploit offshore resources
- to achieve world-recognized excellence in operating on and below ice-covered waters, within five years
- to stand equal or superior to foreign governments or large multinational corporations in developing a current information base about Canada's renewable and non-renewable offshore resources
- to develop and maintain ocean engineering at universities and in government laboratories.

To implement this policy, in 1977, the Interdepartmental Panel on Ocean Management was formed with representatives from departments of Fisheries; Industry, Trade & Commerce; Energy, Mines & Resources; Transport; Indian Affairs and Northern Development.

Source: Canada, Office of the Minister of State for Science and Technology, News Release, "New Oceans Policy," July 12, 1973.

Appendix 2: Oceans Policy for Canada

Reasons for an Oceans Strategy:

1. Canada has extensive oceanic territories. A strategy will ensure Canadians can capitalize on the many development opportunities on this frontier, especially during the critical next five years.
2. There is currently a broad range of federal oceans policies and programs. A framework is needed to ensure that they are coordinated, effective, and efficient.
3. This strategy provides a tangible means of moving forward on major federal priorities – regional development, world-class science and technology, and protection of Canadian sovereignty.

Goals:

- prosperous, dynamic oceanic industries which offer secure, steady employment and economic development benefits, particularly for Canada's coastal regions;

• world-class expertise and capability in oceans-related science, technology, and engineering, which together form the basis for future economic development of the oceans;

• ocean resources and an ocean environment soundly managed and protected for future generations of Canadians; and

• assertion and protection of Canada's sovereignty and sovereign rights over its ocean resources.

Action Plan

i) Stimulating national awareness of Canada's oceans frontier and its importance to our sovereignty and heritage

• National Marine Council

ii) Fostering vigorous, internationally competitive oceanic industries through our industrial development, contracting-out, and procurement policies

• Ocean Mapping, Ocean Information Infrastructure and Ocean R&D

• Ocean Technology Promotion Office. Major functions include:

– providing the private sector with a new window of access to government for ocean technology assistance;

– promoting the use of existing assistance programs in order to improve their effectiveness with respect to ocean technology;

– providing information services for applicants, particularly where more than one federal assistance program needs to be accessed; and

– facilitating joint-venture arrangements involving either the private sector (industry and universities) exclusively, or including the public sector.

iii) Establishing a legal framework which facilitates Canada's ability to achieve the objective and goals of this strategy

• Canada Oceans Act

• Action Within Canada's 200 Nautical Mile Zone

iv) Enhancing Canada's scientific and technological knowledge and capabilities relating to oceans and ocean resources

• Strengthening the International Dimension of Canada's Ocean Sciences

• North Pacific Science Organization

• Coordination of the Oceans Strategy with the Canadian Strategy for Science and Technology

• The Interdepartmental Committee on Oceans

• Marine Science Plan

v) Conserving and managing the living resources of our oceans through prudent stewardship

• Plastic Debris and Driftnets in the Oceans

• Arctic Marine Conservation Strategy

vi) Promoting development and exploitation of the non-living resources of our oceans in an environmentally-acceptable manner

• The Frontier Geoscience Program

• Ocean Mining

Source: Canada, Department of Fisheries & Oceans. 1987. *Oceans Policy for Canada*. Ottawa.

Appendix 3: Arctic Marine Conservation Policy

Purpose

Ensure the future health and well-being of Arctic marine ecosystems, thereby enabling Canada to fulfill its national and international responsibilities in the Arctic and provide for the sustained utilization of marine resources, in particular, use by Arctic peoples.

Principles

The Arctic Marine Conservation Strategy (AMCS) and its implementation will be guided by the following comprehensive principles.

• Canada will exercise its sovereign rights and responsibilities in Arctic marine areas.

• Canada will conserve and protect Arctic marine waters and renewable resources for the benefit and enjoyment of present and future generations.

• Essential ecological components, processes, and systems, and genetic diversity will be maintained in the Arctic marine environment.

• Conservation requires an ecosystems approach and integrated management of renewable and non-renewable resource activities.

• All users of the Arctic marine resources will be recognized. Sustainable utilization of Arctic marine species and ecosystems will be assured for the benefit of all Canadian and Arctic peoples in particular.

• As the primary traditional and current users of Arctic marine areas and resources, the Inuit have particular rights and special responsibilities for the management and use of these resources, the nature and extent of which are being defined through ongoing constitutional and aboriginal claims negotiations.

• The AMCS will promote development of knowledge, information, and understanding of marine systems and resource use.

• Development and implementation of AMCS will reflect and support the social, economic, and cultural needs and values of Arctic peoples. The AMCS will be built through a process of consensus and mutual understanding with the user community and a special sensitivity to traditional values and local customs.

• The implementation of the AMCS will use existing institutions and processes whenever possible. It is recognized that some may require modification, and additional relevant institutions and processes will be developed through constitutional and aboriginal claims processes.

• The implementation of the AMCS will promote international cooperation.

Source: Canada, Department of Fisheries & Oceans. 1987. *Arctic Marine Conservation Strategy*, Discussion Paper, December. Ottawa, p. 11. (Excerpt)

Appendix 4 : the Atlantic Fishery

Atlantic Canada has the largest fishery with total production of $2.04 billion (including aquaculture) and exports of $1.57 billion in 1989. Groundfish accounts for 55% of total landings by volume. Approximately 95% of the 65,000 registered fishermen operate seasonally from privately owned vessels less than 100 feet in length and account for 60% of total landings by volume. The remaining fishermen operate year-round from company-owned fishing trawlers. The processing sector on the Atlantic coast employs upwards of 60,000 people and consists of over 900 establishments, of which only 35% operate year-round. Three integrated companies—National Sea Products, Fishery Products International, and Clearwater Fine Foods—account for well over 50% of production.

Source: Department of Fisheries & Oceans. 1991. (Excerpt)

Appendix 5: The Pacific Fishery

On the Pacific Coast, the fishing industry employs 20,600 fishermen and 6,000 plant workers. Fishing activity is concentrated around the Lower Mainland and Prince Rupert. The production of the Pacific fishery in 1989 was valued at about $893 million (including aquaculture), with exports worth $714 million. The high level of exports in 1989 was accounted for by a significant increase in the shipment of farmed salmon production which accounted for an additional $75 million of production value. Salmon accounts for over 50% of total landings. The harvesting sector is composed largely of vessels under 100 feet in length and processing-sector ownership or financial control over segments of the fleet is significant. Processing occurs in approximately 183 plants, most of which are seasonal. B.C. Packers is the largest producer and accounts for 40% of regional sales. The major markets for Pacific region exports are Japan, Australia and Britain. A recently completed study shows that the financial position of the industry has improved significantly in the past few years and is now very strong.

Source: Department of Fisheries & Oceans. 1991. (Excerpt)

Appendix 6: Chronology of Policies and Events Affecting the Atlantic Fishery, 1981-1990

1981-82 Financial crisis in the processing sector, precipitated by high interest rates and debts related to expansion, soft markets, and bulging inventories. Stock problems relate to gluts rather than shortages.

$15 million in federal government assistance for inventory relief.

1982 Report of the Task Force on Atlantic Fisheries includes 57 recommendations designed to make the industry viable on an ongoing basis.

Restructuring of the major offshore companies and the creation of two new "super" companies through an infusion of government and private sector equity.

Enterprise allocations for vessels greater than 100 feet.

The third UNCLOS adopted by a majority of members of the United Nations.

1985 The federal budget outlines cuts to spending and personnel in the Department of Fisheries and Oceans. 579 person years are to be cut by 1990-91.

1986 Major scientific and administrative reorganization of DFO. Marine Ecology Laboratory in Halifax is closed.

1987 Best year ever for the Atlantic fishery; landed value of $971 million.

Haddock nursery area closure off Nova Scotia, quotas cut sharply.

1989 Discrepancies in assessment figures for the northern cod stock lead scientists to revise their growth figures and recommend a total allowable catch of 125,000 tonnes for 1989, down from 266,000 tonnes in 1988.

Several large groundfish plants in Newfoundland and Nova Scotia are closed.

Report of the Scotia-Fundy Groundfish Task Force (the Haché Report) recommends measures to improve management and control harvesting and processing capacity.

1990 Major offshore companies in Nova Scotia and Newfoundland announce major permanent plant closures.

Report of the Independent Review of the State of the Northern Cod Stock (the Harris Report) recommends measures to insure long-term viability and better management of the northern cod stock.

Atlantic Fisheries Adjustment Program announced in May.

Source: Atlantic Provinces Economic Council, "The Atlantic Fishery in the 1990s: Background to Crisis." *Atlantic Report*, Vol. XXV, No. 2, July 1990. (excerpt)

Appendix 7: The Aquaculture Industry

Over the past decade, aquaculture has seen considerable growth with commercial production concentrating on high-value fish, shellfish and seaweed products for human consumption.

In Canada, large-scale commercial aquaculture production began in the 1950s with trout and oyster cultivation. Within the last 15 years, the aquaculture industry has expanded considerably to include salmon, mussels and Arctic charr. In some regions, the aquaculture sector is diversifying into other species, with the commercialization of scallops and some marine plants. The value of production increased from $7.0 million in 1984 to $145 million in 1989.

[Regarding] industry expansion, in terms of the value of aquaculture output ... recent forecasts suggest that the value of aquaculture production could rise from its current level of 3% of the landed value of Canadian fisheries to 25% or more by the year 2000.

Source: Department of Fisheries & Oceans. 1991. (Excerpt)

Appendix 8: The Cohasset/Panuke Project

The Cohasset/Panuke Project is a proposal to develop and produce light oil (condensate) from the Cohasset and Panuke fields, located approximately 41 km west-southwest of Sable Island on the Scotia Shelf. The two fields are located approximately 8 km apart. The project is to be undertaken jointly (on a 50/50 basis) by LASMO Nova Scotia Limited and Nova Scotia Resources (Ventures) Limited.

Production facilities will be located on a jack-up rig adjacent to the Cohasset site. The oil will then be transferred to a storage tanker moored to a monobuoy. It will then be shipped to market by a shuttle tanker.

Development drilling will begin in the summer of 1991, with the first production scheduled to take place in the second quarter of 1992. The present plan is to produce condensate during the months of April through October for six years. The production rate is estimated to be 955,000 m3/year in the early years of the development and will fall to 810,000 m3/year at year 6. Upon completion of production, the structures will be removed and the wells will be capped and abandoned. ...

The condensate will be transferred from the production rig to a Catenary Anchor Leg Mooring Buoy (CALM Buoy) by a flow line on the sea floor. A storage tanker of 60,000 to 120,000 DWT will be anchored to the CALM buoy and will receive the condensate for transfer to a shuttle tanker. The shuttle tanker will moor to the stern of the storage tanker to load the condensate. It will then transport the condensate to the market destination. ...

The direct project capital expenditures are projected to be $160 million ($1989) over a five-year period. The total estimated operating expenditures are estimated to be $405 million ($1989). It is estimated that 38% of the capital expenditures and 34% of the operating expenditures will occur in Nova Scotia.

The direct, indirect and induced employment over the life of the project (1989–1997) is estimated to average 368 persons per year. The direct employment is expected to be 715 person years during the development phase and an average of 260 persons per year during the production phase.

Source: Cohasset/Panuke Environmental & Socio-Economic Review Commission. 1990. *Report of the Cohasset/Panuke Environmental & Socio-Economic Review Commission*, July, Halifax, N.S., pp. 9-11. (Excerpt)

Appendix 9: Hibernia Oilfield Development

Location and Reserves

The oilfield is 315 km east-southeast of St. John's, Newfoundland, in 80 m of water. It is estimated to contain two billion barrels of crude oil, of which 525 million barrels are expected to be recoverable. The projected life of the field, based on an average daily production rate of 110,000 barrels per day (150,000 barrels per day peak capacity), is 18 years.

There are two productive reservoirs in the oilfield: the Hibernia sandstones at 3,500 m, and the Avalon sandstones at 2,500 m. Estimates show that a total of 83 development wells will be required to produce the field—58 to tap the Hibernia sandstones, and 25 more to reach the Avalon sandstones.

The project has received all regulatory approvals, including approval by an Environmental Assessment Review Panel, and government approval of the Hibernia Development Plan.

Production System

Several production options, including floating systems, were considered before a Gravity Base Structure (GBS) design was selected in 1985. This system has proven itself in the North sea—an environment similar in many ways to the Grand Banks.

The principal components of the production system are the GBS, the Topsides, the subsea installations, the Offshore Loading System (OLS) and the crude oil transport tankers. Much of the engineering, construction and fabrication of the production system components will take place in Newfoundland and other parts of Canada.

Construction of the GBS, assembly of the completed Topsides, and mating of the Topsides with the GBS will take place at Great Mosquito Cove, in Bull Arm, Trinity Bay on the northeast coast of Newfoundland. Bull Arm is approximately 150 km northwest of St. John's, near the communities of Sunnyside and Come by Chance.

Site clearing and road construction began in October 1990. By July 1995, the components of the production system will be assembled and the platform will be towed to the oilfield. Development drilling is scheduled to begin early in 1996, and production is expected to commence in late 1996.

Source: Hibernia Management & Development Co. Ltd. 1991. *Hibernia: Project Update*, January. St. John's, Nfld. (Excerpt)

Appendix 10: Canada–France Fisheries and Boundary Disputes

Background

On March 30, 1989, Canada and France signed two agreements. One refers the boundary dispute off the south coast of Newfoundland to international arbitration. The other establishes interim fish quotas and limits for French fishing in Canadian waters for the period of arbitration.

Boundary Arbitration

France has claimed an Exclusive Economic Zone (EEZ) for the French islands of St. Pierre and Miquelon of approximately 180 nautical miles. Canada has stated that France's rights off the islands are limited to a maritime zone of 12 nautical miles. The overlapping claims generate a "disputed zone" of some 13,700 square nautical miles. The dispute has been referred to international arbitration and Mr. François Mathys has been appointed Agent for Canada.

The boundary tribunal consists of five judges: one appointed by Canada (Mr. Alan Gotlieb), one by France (Mr. Prosper Weil) and three by both countries (Mr. Eduardo Jiménez de Aréchaga, Chairman of the Tribunal, Uruguay; Mr. Oscar Schachter, United States; and Mr. Gaetano Arangio-Ruiz, Italy). The tribunal's decision will be final.

The first written pleadings in the arbitration, called Memorials, were exchanged in New York on June 1, 1990. Counter-memorials were exchanged on February 1, 1991. Oral pleadings will take place in New York in July and August and a decision from the tribunal is expected early in 1991.

Fisheries

The fish quotas agreement includes quotas of non-surplus 2J3KL and Gulf cod, as well as allocations of surpluses primarily in other species for the period of the arbitration. This agreement also provides for new conservation safeguards for the disputed zone: regular and timely reporting of catches, joint inspections, and a commitment by France not to change fundamentally the intensity of French fisheries for non-cod species.

Source: Canada, Department of Fisheries & Oceans. 1991. Briefing Note, March 22. Ottawa. (Excerpt)

Appendix 11: Review Panel on Tanker Safety and Marine Spills

The Public Review Panel on Tanker Safety and Marine Spills Response Capability was appointed on June 9, 1989 by the Right Honourable Brian Mulroney, Prime Minister of Canada, in response to growing public concern for the marine environment resulting from the bulk movement of oil and chemicals through Canadian waters and fishing zones. The three-member panel was given the mandate to review and evaluate:

• the measures currently in place to ensure the safe movement of oil and chemicals by tanker and tank barge through Canadian waters;

• Canada's ability to respond to marine spills of these products;

• the Canadian and international legislation and conventions which regulate the movement of oil and chemicals, including the provisions for compensation for damages resulting from spills.

In fulfilling its mandate, the Panel held 31 days of public hearings across the country. The following are its major recommendations.

Source: Public Review Panel on Tanker Safety & Marine Spills Response Capability. 1990. *Final Report: Protecting Our Waters*. Ottawa, September, pp. i-iii. (Excerpt)

Appendix 12: Oceans Manufacturing and Services

In 1990, the Economic and Commercial Analysis Directorate of the Department of Fisheries and Oceans conducted the first-ever Survey of Oceans Manufacturing and Services. The Survey confirms that this sector is an important contributor to the national economy.

Oceans-related companies are distributed fairly evenly across the country with approximately one-third located in Western Canada, one-third in Central Canada, and one-third in Eastern Canada. British Columbia has the greatest number of oceans companies at 150.

In 1989, oceans companies in Canada generated total revenues of more than $730 million. The manufacturing sub-sector had revenues of some $355 million. The oceans services segment had revenues of more than $378 million last year.

About 8,100 people were employed in the oceans sector last year. Approximately 5,400 or 68% of these were involved in oceans services. This highlights the labour-intensive nature of the services sub-sector.

Canada's oceans manufacturing and services sector is largely export oriented. In 1989, exports totalled more than $420 million, or more than half of the total revenues generated. The primary export market for Canadian oceans companies was the U.S. Exports to the United States accounted for 75% of all export revenues in 1989. Other significant export markets for Canadian companies are the EEC, Japan, and Africa.

Oceans technology is constantly evolving as more is understood about the oceans and their resources. Therefore, investment in research and development is important for Canadian companies to remain competitive in international markets. In 1989, oceans companies in Canada allocated more than $90 million to R&D activities or more than 12% of total industry revenues. The average company invested approximately $81,000 on R&D last year.

The typical oceans company spent $27,000 marketing its products and services. Over half of all companies market their products outside of Canada. In 1989, Canadian oceans companies spent a total of $17 million or 2% of industry revenues on marketing.

Source: Canada, Department of Fisheries & Oceans. 1991. Executive Summary from *1990 Survey of Oceans Manufacturing & Services*. Ottawa, p. iii. (Excerpt)

APPENDIX 13: INVENTORY OF FEDERAL OCEANS RELATED ACTIVITIES

CCG – Canadian Coast Guard
DFO – Department of Fisheries and Oceans
DND – Department of National Defence
PW – Public Works
EMR – Department of Energy, Mines and Resources

EAITC – External Affairs and International Trade Canada
DIAND – Department of Indian Affairs and Northern Development
EC – Environment Canada
ACOA – Atlantic Canada Opportunities Agency
COGLA – Canada Oil and Gas Lands Administration
WDO – Western Diversification Office
NRC – National Research Council
NSERC – Natural Sciences and Engineering Research Council

Program	Dept.	Legislation
1. Marine Transportation		
Marine Navigation Systems	CCG	Canada Shipping Act
Marine Regulatory: Ship Safety	CCG	Canada Shipping Act
Icebreaking & Other Arctic Operations	CCG	Arctic Waters Pollution Prevention Act National Transportation Act
Harbour Management	CCG	Public Harbours & Ports Facilities Act
Hydrography	DFO	Government Organization Act 1979 Territorial Seas & Fishing Act Charts & Publication Regulations
2. Marine Services		
Search & Rescue	CCG, DND, DFO	Safety of Life at Sea Convention Canada Shipping Act
Ice Management/Flood Control	CCG	Department of Transport Act
Eastern Arctic Sealift	CCG	Treasury Board Approval (June 1981)
Marine Architecture & Engineering	PW	Public Works Act
Dredging & Fleet Services	PW	Public Works Act
Small Craft Harbours	DFO	Government Organization Act Fishing & Recreational Harbours Act
Ice Services	EC	Government Organization Act (1970, 1979)
Marine Weather	EC	Government Organization Act (1970, 1979)
Marine Climate	EC	Government Organization Act (1970, 1979)
Offshore Surveys	EMR	Canada Lands Surveys Act (1970) Government Organization Act (1970, 1979) Resource & Technical Surveys Act (1966-67)
Marine Export Transport Services	EAITC	External Affairs Act (1983)

Program	Dept.	Legislation
3. Resource Development & Management (including environmental protection)		
Fisheries Resource Allocation, Licensing & Regulations	DFO	Fisheries Act
Monitoring, Control & Surveillance, Inshore & Nearshore	DFO	Fisheries Act Coastal Fisheries Protection Act
Fisheries Enhancement & Development	DFO	Fisheries Development Act
Habitat Management	DFO	Fisheries Act
Arctic Marine Conservation	DFO	Fisheries Act
Petroleum Development – COGLA	EMR DIAND	Canada Oil & Gas Act Oil & Gas Production & Conservation Act Canada Petroleum Resource Act
Control of Pollution from Land Based Sources	EC	Government Organization Act (1979) Fisheries Act, Section 36-42 Canadian Environmental Protection Act (CEPA)
Environmental Protection re Offshore Petroleum & Mineral Resources	EC	Government Organization Act (1979) Fisheries Act, Section 36-42, CEPA (Part VI)
Toxic Substances Control	EC	Fisheries Act, Section 36-42, CEPA (Part VI)
National Marine Parks	EC	National Parks Act
Control of Ship-Source Discharges	CCG	Government Organization Act (1979)
Marine Environment Protection World-wide	EAITC	External Affairs Act (1982)
Emergencies/Clean-up of Ship-Source Pollution	CCG	Canada Shipping Act
Pollution Prevention in Arctic Waters	DIAND	Arctic Waters Pollution Prevention Act Emergency Planning Orders
Framework for Development of Offshore Non-Fuel Minerals	EMR	Energy, Mines & Resources Act
Offshore Geoscience Information	EMR	Resource & Technology Surveys Act Energy, Mines & Resources Act
4. Sovereignty, Defence and Law of the Sea		
Maritime Boundary Disputes	EAITC	External Affairs Act (1983)
US–Canada Arctic Cooperation & Coordination	EAITC	External Affairs Act (1983)
Law of the Sea	EAITC	External Affairs Act (1983)
International Fisheries Agreements (resources shown for EAITC only)	EAITC	External Affairs Act (1983)
Maritime Command	DND	National Defence

Program	Dept.	Legislation
5. Northern Development		
Northern Land Use Planning	DIAND	Indian Affairs & Northern Development Act
Indian & Inuit Environmental Protection	DIANND	Indian Act
Studies for Northern Oil & Gas Resource Management (NOGAP)	DIAND	Indian & Northern Affairs Act
Granular Resources & Man-made Islands in Beaufort	DIAND	Public Lands Grants Act
Petroleum & Related Environmental Protection – COGLA (resources reported under "C")		
Arctic Icebreaking (resources reported under "A")	CCG	Canada Shipping Act Arctic Waters Pollution Prevention Act
6. Industrial Development		
Action Program	ACOA	Government Organization Act, Atlantic Canada '87
Newfoundland Ocean Industries Development Agreement	ACOA	Economic & Regional Development Agreement
Canada–Nova Scotia Development Fund	COGLA	Federal/Provincial Agreement (1984)
Canada–Newfoundland Offshore Development Fund	COGLA	Canada–Newfoundland Atlantic Accord – Implementation Acts
Western Diversification Program	WDO	Western economic Diversification Act (8 June 88)
Operation & Maintenance of Certain PWC Dry Docks	PW	Public Works Act
International Fish Trade Development	EAITC	External Affairs Act (1983)
Program for Export Market Development	EAITC	External Affairs Act (1983)
7. Marine Science & Technology Development		
Fisheries Resource Assessment Research	DFO	Fisheries Act
Aquaculture Research	DFO	Fisheries Development Act
Habitat Assessment & Research	DFO	Fisheries Act
Resource Development Research	DFO	Fisheries Development Act
Physical Oceanography	DFO	Government Organization Act, 1979
Chemical Oceanography	DFO	Government Organization Act, 1979
Marine ecology	DFO	Government Organization Act, 1979

Offshore Geoscience Activities	EMR	Resource & Technical Surveys Act Energy, Mines & Resources Act
Materials for Offshore Structures Mandate/PERD	EMR	Energy, Mines and Resources
Remote Sensing Relating to Oceans	EMR	Treasury Board Minute Energy, Mines & Resources Act
Ocean Drilling	EMR et al	Cabinet Decision
Marine Engineering (includes $1.5M IRAP)	NRC	NRC Act (1966-67)
Marine Biology & Chemistry (inc. $1.5M IRAP)	NRC	NRC Act (1966-67)
Grant Support to Universities	NSER	C NSERC Act
Climate Research	EC	Government Organization Act, 1979
Defence R&D	DND	National Defence Act
Arctic R&D	CCG	Arctic Waters Pollution Prevention Act
Technology Inflow Program	EAITC	
Industrial Research Assistance Program	NRC	

Source: Economic and Commercial Analysis Directorate. 1989. *Canada's Oceans: An Economic Overview and a Guide to Federal Government Activities.* Ottawa: Dept. of Fisheries and Oceans, Report No. 43, p. 37. (Excerpt)

Appendix 14: National Marine Parks

Environment Canada's Objective for National Marine Parks

To protect and conserve for all time representative marine natural areas of Canadian significance in a system of marine parks, so as to leave them unimpaired for future generations and to encourage public understanding, appreciation and enjoyment of Canada's marine heritage.

National Marine Park System

Marine parks will be established to protect and conserve representative examples of the diversity of Canada's coastal zone and oceans for the benefit of present and future generations. Based on current scientific information, Canada's oceanic and Great Lakes areas have been preliminarily divided into 29 marine natural regions. Ideally, each of these marine regions should be represented in the system of national marine parks....

Federal-provincial/territorial agreements to create marine parks will be significant steps in the process of national marine park establishment. They will commit different levels of government to common objectives: to conserve a designated marine park area, and to encourage understanding and enjoyment of the area by this and future generations. Without the support and cooperation of the provinces, territories, native organizations and the general public, the federal government will be unable to meet its responsibility to protect the marine heritage of all Canadians.

Source: Environment Canada – Parks. 1986. *National Marine Parks Policy.* Ottawa, p. 6. (Excerpt)

5

Recent Developments in Mexico's Coastal Areas

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INTRODUCTION

Seventy percent of the surface of our planet is water, which provides for our basic needs. The oceans make our world hospitable, because of its capacity to store heat, moderate cold winters and temper the heat of summers. No health or development program for animals or humans can begin without planning for sufficient water. It is of fundamental importance in connecting the gulfs and seas that sculpt islands and continents.

From the beginning of history humans have built their cities near seas, recognizing their importance for sustaining life, and building the close relationships which human civilization would always have with the oceans.

Today, thanks to satellite photography, scientific groups can detect changes in remote areas, and analyze possible temperature modifications due to changes in the ozone shell. From space, scientists can observe changes that are reflected in the oceans. The oceans have become the starting point for new programs to improve the quality of life on earth.

BACKGROUND

Mexico has 11,600 kilometers of coastline, and 2,892 million square kilometers of patrimonial waters. Half of the surface of the country offers attractive possibilities for development: industry, fisheries, rearing livestock, energy generation, aquaculture, export industries, transportation and tourism.

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In the Gulf of Mexico, at Campeche Sound, offshore oil exploitaìtion provides "black blood" to the country for its own use as well as for export. For basic and secondary petrochemical industries, "La Cangrejera" in Coatzacoalcos is a large industrial complex which yields nearly 3 million tons of 25 different products, making it the largest among others, namely Tamaulipas, Tehuantepec's Istme, etc.

Mexico operates 25 commercial harbors and 77 fishing harbors. In terms of shipyards, at least 6 harbors have important installations, among them, Veracruz, Tampico, Salina Cruz and Ensenada. The yield in salt production taking place at Guerrero Negro California is among the largest in the world.

Several harbors have facilities for cruise and ferry ships, and in several areas yacht marinas have been built or are under construction. Tourism holds great potential for Mexico thanks to its unique beaches and warm waters. Large hotel complexes, villas, time-share condominiums and golf courses are operating and many more are under development in the resorts of Acapulco, Ixtapa, Puerto Vallarta, Mazatlán, los Cabos, Huatulco, Isla Mujeres, Cozumel and in the Carribbean area between Tulum and Cancun.

For superior education in ocean-related fields, academic research institutions operate in La Paz, Guaymas, Tampico and Mazatlán, awarding graduate degrees in fields such as physical and biological oceanography, biochemical engineering, food technology, marine and harbor engineering, and many others.

USING APPROPRIATE TECHNOLOGY FOR POOR AREAS

As a developing country, Mexico faces limitations in terms of economic resources. Heavy construction equipment that is available is used in high priority projects. Since it is impossible to cover all developments along Mexico's coastlines, we will mention as an example Chacahua, a very small village of fishermen in the state of Oaxaca.

Chacahua has an interesting coastal lagoon that, while connected with the ocean, produced shrimp, oysters and other seafoods. When the connection with the sea was closed by littoral drift and continual dry seasons, it remained that way for several years, creating food shortages for the fishermen and their families. With the help of the Ministry of Fisheries, the fishermen built a small breakwater. They placed an anti-scouring mat at the site and used a small motor pump to hydraulically lift sand into synthetic containers. This relatively simple technology, along with labor donated by the people of neighboring towns, enabled the citizens to reconnect the lagoon with the ocean. With tidal action, the opening became larger and more stable, and once again, this small fishing village could flourish.

Using a minimum of construction equipment, labor provided at no cost by fishermen and villagers, and with the help of an engineer with a Ph.D. in sociology, this project was possible. This engineer has spent his life as an advisor to the United Nations, and with these native peoples on the Mexican coast.

MULTIPLE BARRIER CONCEPT

Among the great hazards of nature — earthquakes, floods and tsunamis — we can assume that hurricanes, cyclones and typhoons can be forecast and preventive measures taken to diminish their devastating effects on the coastlines of affected areas. We can learn from nature itself, observing other areas, such as the Caribbean and south Pacific areas, where natural features such as coral reefs and rock outcroppings protect sea lagoons and coastal areas from destructive wave action.

The efficiency of manmade structures is related to their optimal dimensions regarding the width of the crown and the elevation or submersion of the structure above or below sea level. We propose an original concept for an offshore anti-hurricane coastal barrier, composed of several artificial multipurpose reefs placed strategically to dissipate wave energy. The methods used will minimize investment and construction times.

One solution could consist of two submerged parallel structures at a relatively close distance, which would act as one single wide-crowned obstacle. Dredged material would be confined between the two structures, dissipating the destructive effect of very long period waves.

A second solution is a similar arrangement, without dredged material between the structures. Energy received by the first structure would be dissipated, part reflected, and the rest minimized by the next structure.

A third solution is a multiple purpose barrier complex, the first line in deep waters to dissipate hurricane waves to some extent, a second line of defense for common waves and a third line near the shore to confine and retain a series of beaches.

In support of this concept, scientific studies have suggested the most logical arrangement for optimizing the dissipation of energy by a double lateral expansion around each artificial reef. Computer models have helped to determine, for different ocean conditions, the optimal dimensions and design for the structures. Simultaneously, in large flume wave tanks, different spectrum waves are being tested for various sizes, separation and patterns of artificial reefs. This innovative concept has already been used for several beaches in Mexico, and early results are encouraging. Important research will continue in order to gather the data and develop design criteria for coastal engineers around the world. The multibarrier man-made reef could ultimately provide an intelligent means to considerably reduce the destructive effects of natural hazards such as hurricanes, cyclones and typhoons.

CONSTRUCTION PROCEDURES

With conventional construction, the multibarrier reef is very expensive to build, and perhaps this is the key reason that this solution has been implemented in very few places in the world. Existing man-made reefs are constructed with quarry rock or precast concrete, and construction requires heavy marine equipment, large volumes of material, relatively good sea conditions, long construction time, and very high investment.

Recent advances in polymer development, in connection with ingenious construction methods, allow innovative procedures to build artificial reefs with materials largely available in the sea. With small boats supplied with electric generators and air compressors, a team of divers can hydraulically confine sand inside large sythetic containers using special submersible pumps. This increases the weight of the container from a few kilos to several tons in a matter of minutes, placing these heavy construction elements in the exact places required without cranes or other heavy equipment.

With an adequate antiscouring mat, ballasted on the edges, the slopes of the artificial reefs constructed with these "sandtainers" can be steep. On top of that, using placement patterns first suggested by Richard Sylvester of Australia Western University, the artificial reefs can be constructed using a minimum number of sandtainers.

The damage left in the path of Hurricane Gilbert in 1988 was enormous in Mexico, particularly on the Yucatan Peninsula and the Tamaulipas coastline. The solution proposed to protect Cancun, a tourist resort on the Yucatan Peninsula, is a multiple line of artificial reefs. The first line of reefs, constructed at depths of 11 meters, would minimize the energy of storm waves; a medium series of reefs at depths of 4 meters would stabilize the beach profile; then a series close to shore would confine beach sand and protect tourist facilities and shoreline construction.

DISCUSSION

While it is widely accepted that many coastlines are subject to the risks of tsunamis, hurricanes and typhoons, engineers in developing countries often lack the economic resources to address the hazards caused by these natural phenomena. The proposed hydraulically confined sandtainers represent a "soft solution" to these problems that can be easily implemented, as it is easy to sculpt the size and shape of the artificial reef. Once built and seen in action, it is easy to remove or add units to the structures to optimize their effectiveness.

Once the shape, size and position of the reef proves to be adequate, it is possible to reinforce it by building, in exposed areas, a "seacrete" artificial shell. This is done by placing chicken wire mesh connected to a negative current pole and strategically placing carbon anodes connected to a positive pole. Direct low voltage, high amperage electric current is applied, and electrolysis of the minerals in seawater occurs and is fixed on the wire, in a process similar to that which builds marine shells.

CONCLUSION

For developing countries, these artificial reefs represent a viable, relatively inexpensive means of protecting shorelines as well as providing training and work for local populations. For highly developed countries, this offers an environmentally preferred alternative to conventional reef and breakwater construction using quarried rock and other materials.

As submerged structures, the multibarrier reefs can also be considered multipurpose submerged structures. With reduced wave impact and large exposed surfaces, in very short time benthic diatoms and algae fix to the sandtainers, attracting marine life and small fishes. For fishing villages, aside from protection, new fishing areas are created, saving time and the fuel used in traveling to fishing grounds further away. For tourist resorts, the reefs create safer beaches, minimize rip currents and create areas for snorkel and scuba divers.

With damage to the ozone layer confirmed and the great degree of atmospheric pollution contributing to that damage, the world's climate is changing, with the risk of hurricanes, typhoons and cyclones being stronger and more frequent. It is thus wise to examine low cost alternatives, such as artificial reefs, to minimize the damage caused by these events. The results of our mathematical models, hydraulic laboratory studies and ocean experiences of the past twenty years are useful for engineers all over the world seeking to protect coastal areas.

(Edited by P.M. Grifman)

6

USSR Coastal Zone Utilization Priorities and Concerns of New Government Policies

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The policy of the USSR in the sphere of littoral oceanic utilization was formed during the post-war period, especially during the 1970s and 1980s, as a result of the cooperation of the main ministries and agencies related to marine activity: Ministry of Defense (Navy), Ministry of Fishing Industry, Ministry of Marine, Ministry of Geology, Ministry of Oil and Gas Industry, the USSR State Committee on Science and Technology, the State Committee on Hydro-Meteorology and also the USSR Academy of Sciences. In addition, their own policies were formed within the frameworks of the above mentioned State institutions. But the general priorities of the State reflected to a considerable extent the authority and influence of a given agency, and also the objective realities of an internal and external political and economic character.

In this connection, it is quite evident that military aspects occupied a strong principal priority position (see Table 1) in USSR marine policy. The priority character of the scientific research is explained by both their special applied military importance and the traditions of the development of a number of spheres of knowledge formed during numerous decades in the USSR. A significant role was attached to the fishing industry in connection with an acute food problem, a shortage of animal protein, and also an aspiration for entering the world markets for fish and fish-products.

Editor's Note: This paper is presented here as it was prepared for COSU II, prior to the reorganization of the Commonwealth of Independent States.

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Table 1

Priorities of the State Policy of the USSR in the Sphere of Littoral Oceanic Research and Utilization

	1970-80	2000*	2000**
Military objectives	1	7	2
Scientific research	2	3	3
Bioresources utilization	3	4	4
Marine development and ports	4	6	5
Mineral resources utilization	5	4	4
Recreation and toursim	6	1	7
Environment protection activity	7	2	6

* Under the conditions of considerable progress in the development of democracy and an introduction of market relations.

** In case of considerable progress in the development of market relations under an authoritative regime of the government.

Environmental protection activity occupied a steady last position in priorities in spite of the fact that it existed in the so-called "Complex programmes" and plans of the development of various regions of the country. It should be noted that the above-mentioned Programmes intended to relax agency pressure in the economic policy of the country could not accomplish their tasks owing to their bulkiness and to an inclusion of numerous components. They proved to be especially inefficient in the sphere of solving the problem of rational utilization of littoral zones. A fragility of the ecosystem of the littoral oceanic area, its direct dependence on processes on the adjoining stripe of land — all this requires an objective, purposeful independent policy in the sphere of control over littoral zones. The world practice confirms this fact. Lack of such a policy decreases the efficiency of economic activity in the littoral zone and threatens its ecological health to a special extent. The practice of the USSR is a confirmation of this fact.

A critical situation has been formed by the development of industry and agriculture in a number of littoral regions of the country. A particularly complicated ecological situation is observed in the littoral-shelf zones of the Black, Azov, Baltic and Caspian Seas. The Aral Sea zone has been declared a zone of ecological disaster; a catastropic socio-economic and ecological situation has been formed in the regions adjoining the northern part of the Caspian Sea.

The number of valuable fisheries resources and sea animals is decreasing. The contents of contaminating substances in sea sediments is increasing, as maximum concentrations are noted in nearshore zones and bays.

An aggravation of the ecological situation in the sea zones and especially in the shelf zone conditions the necessity of taking efficient environment protection measures for: a reduction of direct disposal of contaminating substances into the marine environment; a reduction of volumes of industrial and commercial sewage coming to river systems; an avoidance of the washing-off of soluble substances from agricultural areas, etc.

Not so long ago, it seemed that consideration of these factors and formation of a general State programme for littoral oceanic area utilization and control was a complicated matter, but possible in forseeable projects. At present, however, the situation has become even more complex, because of aggravation of the economic situation of the country as well as because of the problems demarcating jurisdiction among the members of the Federation. Centrifugal trends which have been manifest quite clearly hamper not only the formation of a general State policy in this sphere but also a prediction of its development in the coming years.

Declaration of an intention not to sign the Union Treaty on the part of four out of six "sea" Republics (Georgia, Latvia, Lithuania, Estonia), a radical reappraisal of the concept of sovereignty and sovereign rights for the utilization of resources in the two biggest Republics of the country — RSFSR and Ukraine, a "legislative" confrontation between the centre and RSFSR and a number of Republics make formation of a general State programme for control of the littoral zone to be improbable. In this respect, prospects for the formation of Republican and in some cases inter-Republican programmes, with coordinating efforts of the Centre and a special preoccupation with an ecological justification of efforts at local and Republican levels, a proliferation of the information, data, new technologies and a realization of the complex R&D, look like to be most probable.

Proceeding from this specific situation the problem of littoral zone utilization and control may be solved in various ways.

Some specialists consider that the problems arising in regulating the utilization of natural resources of the Caspian Sea could be solved by assigning zones of responsibility to the Republics. At the same time, every Republic should solve the problems related to navigation and to the utilization of organic and mineral resources of the sea and its adjoining territory within its zone of responsibility. The share of the profit received from the utilization of resources within the zone of responsibility is compulsorily assigned to the Republic responsible for control and utilization of sea resources within this zone. At the same time, this Republic is also responsible for environment protection.

To realize general control over the state of the environment and resources of the Caspian Sea within the frameworks of inter-Republican and international cooperation, it is necessary to form a corresponding structure of agencies for solving ecological problems. Similar proposals are being studied concerning other Seas too. Thus, the concern "Aral" is formed for the Aral Sea according to the decision of the Union government, and a State Committee on the Protection of Aral will also be organized.

With the purpose of improving the ecological situation of the Black, Azov and

Aral Sea basins, an elaboration of inter-Republican programmes for the ecological situation in these regions is in progress. As for the Black Sea, there are proposals for creating a joint economic zone (the USSR, Turkey, Italy, etc.)

But on the whole, it should be noted that the problems of the marine-tenure are still insufficiently studied while taking ecological and other factors into account. The latter hampers the progress of the utilization of sea resources in a number of ways.

A complex ecological and economic justification of various directions for the utilization of the littoral zone, continental shelf, territorial waters, economic zone of the USSR would allow for optimizing expenditures necessary for sea resources utilization and also for reducing the concomitant damage. A realization of a comprehensively grounded policy for the utilization of varied sea-resources is necessary with these purposes in view.

On the whole, the solution of the problem should proceed from the basic premise that in the nearest future during a transitional period towards a market economy the burden of control over the protection and utilization of sea resources in the internal waters and marine economic zone of the USSR would be transferred from the central agencies to regional organs of control while preserving strategic functions of development and general coordination in this sphere. New organs of control over sea resources should be formed depending on the scale of the utilization of resources and other conditions.

Initially, it is necessary to develop the Concept of Control Over Protection and Utilization of Resources in internal waters and the sea zone during a transition to a market economy. The Concept should be based upon stable progress of the national economy of littoral regions and the country as a whole without disturbing the balance of littoral and marine ecosystems.

The basic principles on which the sea resources control system should be based are the following:

- — a cadastre character or registration of sea resources (mineral resources of the littoral zone, bioresources, recreational utilization, etc.)
- — a regional character of regulating the natural sea resources distribution, utilization and protection;
- — an economic interrelation of the distribution, protection and utilization of resources;
- — an economic estimation of resources;
- — a priority and competitive character of the distribution of resources between users;
- — a complex character of the formation of a regional sea resources control agency.

A realization of the general principles will require a certain transitional stage and also the accomplishment of a number of measures, including:

1. To form littoral zone control agencies in large regions of the country including the continental shelf and the economic zone. Such agencies could be formed on a basin principle and could be of both an administrative and scientific and consultative character.

2. To develop and introduce a new order of sea resources distribution between users (enterprises) with different forms of property.
3. To form regional cadastres of sea resources with a definition of their economic estimation, to introduce the system of payments for a utilization of any kinds of resources.
4. To realize a revision of the price system (wholesale and retail prices) for sea products while taking the world prices into account.

In case of acceptance of the above-mentioned principles it would be necessary to elaborate the All-Union objective programme of measures for creating a corresponding structure of control, to adopt normative legislative acts, and to allocate the necessary financial resources for realization of R&D programmes.

(Edited by P.M. Grifman)

7

Coastal Engineering Research Activities in Taiwan, ROC

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ABSTRACT

With continuous development of the economy, activities along coastal Taiwan are gradually increasing. Harbors are the traffic points and coastal areas are becoming industrial fields or recreation areas; thus, how to use coastal space effectively is going to be an important theme. Oceanic technology has a close relationship with technology development in Taiwan. Development of oceanic engineering and technology is an important part of oceanic technical development. For coastal engineering, naval architecture and harbor engineering, manpower is sufficient, and research results have been presented in the past.

Because of the importance of coastal shipping and harbors, organization of present manpower and enhancement of integrated research of major problems are the future key issues. The major research topics in the future are as follows:

1. Investigation of basic data of ocean meteorology;
2. Study of elementary characteristics of wave and ocean current;
3. Coastal sand drifting and topography;
4. Coastal construction and coastal protection;
5. Development of tidal land and artificial islands;
6. Coastal planning.

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GEOGRAPHICAL CHARACTERISTICS OF TAIWAN'S COAST

The elliptical-shaped island of Taiwan is located in the western Pacific, separated from mainland China by the 100 km wide Taiwan Strait. The eastern half of the island consists of a metamorphic complex of the upper Paleozoic age. The coastline around Taiwan has a length of about 1,600 km with different geomorphological characteristics, though it is rather straight. The Coastal Range, bordering the east coast, is formed of Miocene volcanics and younger sediments. The western foothills of the Central Range are composed of Tertiary sediments that contain coal seams and some oil and natural gas. Stable coastal lands, capped with lateritic soil, are found on the western half of the island of Taiwan.

Since Taiwan is situated in the mobile belt of the western Pacific, some tectonic events are revealed by coastal features. The present form of the coast also reflects both the marine processes operating upon the coastal area and the geological background of the island.

Tremendous amounts of silt, sand, and other erosional products derived from upstream areas are brought down to the coast, forming broad tidal flats and chains of offshore barriers. The longshore current, driven by winds during the monsoon period, accelerates the movement of sediment along the western coast, and is favorable to pro-gradation. This phenomenon is common in southwestern Taiwan.

The sea floor in Taiwan Strait is mostly at depths of 50-100 m, but it becomes deeper toward the Pacific, with the greater depths exceeding 3,000 m. Other factors affecting coastal development are the monsoon climate and typhoons. The winter monsoon from the northeast begins in September and ends in May of the next year. The summer monsoon from the southwest lasts from May to September. The velocity of wind during the monsoons is 5-15 m/s.

Typhoons occur several times during the summer, generating high, stormy waves that attack the coast, usually lasting for 24 hours or so.

The tidal range is up to 4 m on the western coast, whereas the rest of the coast experiences only about 1 m in average. For this reason there is a broad tidal flat in the west, parts of which have been reclaimed for agricultural uses.

The coast of Taiwan may be classified into five types according to their nature at the present stage of development. This is simply the result of marine action on the coast under various geological controls.

Type A. The advancing coast resulting from emergence and accretion. The coast from Taisi to Tainan, in the western part of the island, is apparently an advancing coast. Much sediment brought down from rivers originating in the central mountains provides material for the formation of tidal flats and offshore barriers. Continuous uplift of this area since the Pleistocene has also contributed to the advancement of the coast.

Type B. The retreating coast resulting from emergence and considerable erosion. Both the northern and southern extremities of the island have been continuously uplifted since the Pleistocene. Marine terraces of coral reefs have been well developed in the Oluanpi area in southern Taiwan. The highest one has been elevated over 200 m above sea level. Living corals are also abundant along the coast near Oluanpi.

Though one sees evidence of recent uplifting in northern Taiwan, there has also been a fluctuation of the coast in the past. The scenic hoodoo rocks in the Yehliu area are remnants of concretionary subaerial sandstone, emerged after undergoing marine erosion.

Type C. Retreating coast resulting from submergence and marine erosion. The coast near Yilan in the northeast of Taiwan, and the sector from Fengkang to Kaohsung in the southwest, are retreating coasts resulting from regional subsidence and marine erosion. Arid coast and land-tied islands are seen near Suao. The farmland of the Yilan plain has been protected from the invasion of seawater by coastal dunes and dikes. The coast from Kaohsung to Fengkang has also been retreating because of erosion from the waves generated by southwest monsoon winds. A drowned valley is located offshore.

Type D. Retreating coast of fault origin. The coasts near Hoping and Tawu, in eastern Taiwan, are both of fault origin, showing a straight and simple coast with continuous sea cliffs.

Type E. The coast of equilibrium, eastern Taiwan. Chengkung is a small fishing port located at the sea side of the Coastal Range, which has been tectonically active since the Pleistocene. The range has been uplifted at different rates in different places. Since the coast faces the high seas of the Pacific ocean, erosion offsets the amount of land gained by upheaval, and the coast has almost reached a state of equilibrium. At Taitung, a delta is locally prograding at the present time.

DEVELOPMENT OF COASTAL AND OCEAN ENGINEERING IN TAIWAN

The economic development of Taiwan, an island province of the Republic of China, is highly related to coastal and ocean engineering. The activity of coastal and ocean engineering contributing to the economic development in Taiwan encompass: (1) expansion of useful land area, (2) construction of harbors for import, export and fishery development, (3) offshore exploration and development of petroleum and marine resources, and (4) protection of coastal land against beach erosion, storm surge, and waves. In the past, the achievements of these activities may be summarized as follows:

Tideland and nourished beach reclamation

In total, more than 7,000 hectares (ha) of tideland have been reclaimed for farmland, fish ponds, salt fields and housing areas. The government also initiated many projects to reclaim more than 50,000 ha of tideland for industrial or other use on the west coast in the future.

Harbor and terminal construction

In order to relieve the shipping congestion in the existing Keelung and Kaohsung harbors, in 1971 the government started a long-term project which included the expansion of Keelung, Kaohsung and Hualien harbors, and construction of new harbors, among which Taichung harbor has the largest scale. An artificial harbor located on the mid-western coast of Taiwan, its total area is about 30 square kilometers, 10 km long along the coast and 3 km wide between the original shoreline and the western breakwater. The first stage construction of engineering works was completed in 1976. During construction, the harbor started shipping operations.

As far as the fishery industry is concerned, Taiwan has about 15,000 fishing boats and 153 fishery harbors and docks. Because the fishing boats have become larger in recent decades, most fishery harbors and docks have problems with insufficient water depths and basin spaces. In order to improve this situation, the Taiwan Fisheries Bureau completed a nine-year project in 1987 as the first stage for enlargement of existing fishery harbors and building new ones. The second stage project is now underway.

Taiwan imports a large amount of petroleum annually. Many terminals are required for discharging petroleum from tankers. One discharge terminal was constructed inside the Shen-Ao Bay in northern Taiwan, and two single-point moorings appear to be better suited to exposed locations than a multibuoy mooring for a large tanker.

Shore protection against beach erosion, storm surge, and waves

The total length of the coastline in Taiwan is about 1,600 km, of which 481 km, especially in the beach erosion areas, is protected by sea-dikes. The northwestern and southwestern coasts suffer from beach erosion problems which are due to reducing sand drifts from rivers or mean sea level rising, or land subsidence. The mean sea level in the southern coast rose about twenty centimeters in the past twenty years. In the meantime, land subsidence reached 2.3 meters in the most severe area of the southern coast. Both mean sea level rising and land subsidence cause beach erosion at a rate of 1:15 to 1:25 (vertical: horizontal).

Research developments on coastal and ocean engineering

The university, Institute of Harbor and Marine Technology (IHMT) and related authorities have engaged in investigation and research on coastal and ocean engineering for more than three decades. Their achievements have been presented and published in various international conferences or symposiums. A conference on coastal and ocean engineering is held in Taiwan annually for exchanging knowledge and the results of studies and experiments. Some subjects in the latest proceeding are listed follows:

(1) Application of local radiation conditions to water-wave numerical modeling — the mild-slope equation is employed to solve wave field in coastal areas.

(2) Simulation of grouping waves — a process for generation of irregular wave trains in the wave tank including given wave grouping characteristics has been developed.

(3) Wave response simulation for an offshore coal terminal including diffraction, refraction, reflection and boundary dissipation — a finite element model for computing responses of complicated coastal basin including harbors and/or offshore breakwaters is presented.

(4) Boundary element simulations of nonlinear wave generation — boundary element numerical model for the simulation of transient, nonlinear free surface waves is developed.

(5) Numerical model of wave oscillations in porous-wall harbors of variable depth — a systematic approach to obtain the characteristic curve and the resonant period of wave induced oscillation in porous-wall harbors of variable depth is established.

(6) Application of numerical simulation of the nearshore current and pollutant dispersion — develops a numerical model to simulate the distribution of the nearshore current and the concentration of the pollutant dispersion by using finite element method.

(7) Combined effects of wave refraction-diffraction and currents to verify the results of numerical calculation, a model (1:100) of a large cylinder located on slowly varying water depth is employed for experimental studies.

(8) A study of sea water flushing — based on tidal wave hydrodynamics and using fluid mechanics equations, related mass transport conditions to calculate the harbor or basin sea water flushing characteristics.

(9) Primary analysis on wave-current interaction — aiming at the theoretical analysis on interaction of regular progressive gravity wave and steady uniform flow.

(10) The reflection & transmission of a semi-circle perforated breakwater — examining the reflection and transmission characteristic of a semi-circle perforated breakwater through regular and irregular wave.

(11) Wind tunnel test of two-dimensional windbreaks in Taichung harbor — the effects of windbreak height and porosity were studied.

(12) Wave absorption by a porous wall of finite thickness — investigating the reflection of small-amplitude surface waves by a porous wall of finite thickness.

(13) The investigation of dynamic pile test in coastal areas — to execute dynamic pile analysis with Pile Driving Analyzer and CAPWAP program.

(14) Properties of high-strength fly ash concrete: a prospective material for offshore structures — to investigate the feasibility of applying high-strength fly ash concrete to the offshore structures.

(15) On the wave and current field at vicinity of Haw-lian harbor.

ORGANIZATION AND MANPOWER FOR RESEARCH AND DEVELOPMENT ACTIVITIES ON OCEANIC TECHNOLOGY

The National Science Council (NSC) is a government agency in charge of science and technology affairs in the Executive Yuan of the Republic of China. One major mission of the NSC is as a staff to the Executive Yuan: (1) to recommend and promote national science and technology policy; (2) to coordinate and evaluate research and development projects.

Another mission is as a funding agency: (1) to promote and support academic research; (2) to support, in conjunction with the Ministry of Education, the training and recruiting of scientific and technological manpower; (3) to promote international cooperation in science and technology.

Because oceanic technology has a close relationship with the technology development of the country, research and development of oceanic engineering and technology is also an important part in the oceanic technical development. The Engineering & Applied Science Division of NSC composed a planning group to consider that oceanic engineering and technology should be included in the key-subjects provided by NSC to be carried out persistently. After much consultation, discussion, and surveying existing information, the research topics of oceanic engineering and technology are divided into seven groups: (1) underwater technique, (2) coastal engineering, (3) naval architecture, (4) oceanic environment engineering, (5) harbor engineering, (6) offshore engineering, (7) oceanic resource engineering.

Recognizing the trend that more resources for human needs must be obtained from the ocean, the Ministry of Economic Affairs (MOEA) of Taiwan, Republic of China, launched an effort beginning in late 1987 to develop a R&D program in ocean resource utilization. Energy and Resource Laboratories (ERL), a member institution of the Industrial Technology Research Institute (ITRI) of the Republic of China, has recently formulated a proposal for a 5-year program to develop ocean technologies. With this sponsorship, this program represents the nation's most aggressive effort to date in utilization and preservation of ocean resources.

The Institute of Harbor and Marine Technology (IHMT) is also a governmental organization established in 1981. The major duties of this institute are to carry out research and development of harbor engineering technique and to engage in training and educating harbor engineers. In the future, IHMT will play an important role in solving harbor and marine problems.

Presently, over 160 persons with postgraduate degrees are involved in the field of ocean engineering. Training in the field at Taiwan University and Cheng Kung University, Sun Yat-Sen University, Marine and Oceanic University, Energy and Resource Laboratories and United Ship Design & Development Center will increase manpower over the next several years.

FUTURE PLANS FOR RESEARCH IN COASTAL ENGINEERING IN TAIWAN

As the economy continues to develop, activities along coastal Taiwan will gradually increase. Harbors are becoming the traffic points and coastal areas are becoming the industrial fields or sight-seeing regions; thus, how to use coastal space effectively is an important theme. Because of the unpredictability of the ocean, scientific technique is used to decrease the potential for natural disaster and increase human welfare. Coastal sand drifting, with complicated phenomenon, is ready for academic investigation. Because of problems of scour and deposit due to the sand moving, construction for protecting the coast and for effective usage of coastal regions are inevitable.

Six objectives planned for the future on the costal engineering are listed as follows:

I. Investigation of basic data of ocean meteorology

It is helpful to understand the physical phenomena by observing the field of interest. Engineering planning and design also need lengthy observation data. But, the observation data of climate, wave, ocean current and tide along coast in Taiwan are not complete. The major study items required are:

(1) development of observing equipment system
(2) observation and analysis of ocean meteorologic data
(3) related study investigating theory and data quality
(4) analytical study on numerical data
(5) study on remote sensing for ocean

II. Study on elementary characteristics of waves and ocean current

Wave studies are one of the major study topics in coastal engineering. For example, the motion of ocean current, sand drifting and coastal constructions are based on wave theory. Wave motions involve phenomena of shoaling, refraction, diffraction and breaking when move into coastal regions. The practical problems in coastal engineering need study on basic characteristics of waves, as well.

The major study items are:

(1) mechanism of wave dynamics
(2) phenomenon of coastal waves, for example, shoaling, refraction, diffraction, breaking waves and short wave
(3) study of nonlinear and orientation of waves
(4) development and estimation of wind waves
(5) study of the interaction between waves and current
(6) influence of construction on waves and current
(7) coastal current system

III. Coastal sand drifting and topography

Sand drifting is the movement of bed material initiated by waves or current. Its motivation and moving direction are affected not only by external forces, but by topographic factors and the size of bed material, and cannot be estimated by theories; therefore, field surveys must be made instead. For simulation of natural conditions, hydraulic model experiments with movable beds should be conducted. The major study items are:

(1) the relationship between coastal current and sand drifting
(2) related study of the boundary layer at the bottom of sea
(3) analytical and numerical modeling for investigating variation of coastal topography
(4) variation of coastal topography around estuaries
(5) model experimentation of sand drifting
(6) investigation and study of coastal sand drifting in Taiwan
(7) kinematic characteristics of suspended sediments

IV. Coastal construction and coastal protection

Coastal constructions are used for resisting wave energy and protecting land inside. In western part and southern part of Taiwan, the fast development of breeding fisheries results in ground settlement by overpumping groundwater. Then, the height of sea wall is not enough for protection from big waves. Hence, enhancement in research work in coastal protection should be required.

The major study items are:

(1) study of the relationship between sea wall, breakwater and detached wave breaker
(2) study of the relationship between intrusion of sea water and ground settlement
(3) technical study on making seashores
(4) study of coastal erosion and its prevention
(5) study of deposition at estuary
(6) storm tide and tsunami
(7) technique of coastal engineering

V. Development of tidal land and artificial island

In systematic planning and developing for coastal areas, extra land resources will be expected. Although there is experience in developing tidal land in Taiwan, study and planning for tidal land should be continuously strengthened. Moreover, isolated or artificial islands could be planned to build nuclear power plants for decreasing environmental contamination. The major study items are:

(1) study of elementary data needed for location selection and construction designing
(2) constructing artificial islands and coast location selection, investigation of location, planning and designing, modification of foundation and others

(3) study of space usage of isolated islands
(4) study of techniques of investigation and maintenance of artificial land
(5) study of bridges across the sea

VI. Coastal planning

Coastal areas can be developed for the use of industry, commercial fishery, urban region and recreation. The proper arrangement of usages in coastal areas results in optimum development. And fishery resources in water should be protected, managed completely, and planned considerately. The major study items are:

(1) study of the protection of the natural environment around the coast
(2) study of the development of coastal breeding areas
(3) study of the development of coastal sightseeing and recreation areas
(4) study of coastal reservoir and lake estuaries

CONCLUSION

Manpower for coastal engineering, naval architecture and harbor engineering, is sufficient, and many research results are available. Because of the importance of the coast, shipping and harbors, organization of present manpower and enhancement of the integrated research are future key issues.

In the past, no attention has been paid to underwater technique. At present, strengthening training and manpower in this field and aggressively pushing work in this area should proceed.

With the development of industry, commerce and sightseeing, environmental problems are increasingly important. Study of oceanic environmental engineering also needs to be pushed positively.

The land resource in Taiwan is so limited that development and usage of ocean resources are important. And the research work in offshore engineering and oceanic resource engineering needs to proceed, too.

During the process of planning an even bigger picture has emerged. Taiwan should not be limited to the immediate time and space in the scope of ocean technology development. Strategically and geographically, Taiwan should assume the role of technological leader for the whole region for decades into the future.

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Coastal Zone of Korea: Status and Prospects

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ABSTRACT

The coastal zone of the Republic of Korea has been intensively used for various purposes, including fishery, mariculture, marine transportation, reclamation, industrial activities, tourism and waste disposal. The lack of coordination among several governmental bodies responsible for regulating various coastal activities, has resulted in serious conflicts between different coastal uses. In addition, under the development-oriented national policy, the issues of environment conservation have received a low priority in the process of decision making.

In the mid-1980s, with increasing recognition of the importance of our coastal resources and growing public concerns about environmental degradation, the Korean government embarked on efforts to formulate a comprehensive management program for the Korean coastal zone.

INTRODUCTION

The Republic of Korea (Korea hereinafter), bordering on three seas with totally different oceanographic conditions, has a relatively long coastline of 12,789 km, including the coastlines of approximately 3,300 islands, about half the length of that of Japan and a quarter of that of the United States (Table 1).

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Table 1

Coastline of Korea (km)

	Korean Penninsula	R.O.K.	North Korea
Land	8,497	5,560	2,937
Island	8,234	7,229	1,095
Total	16,281	12,789	4,032

Source: Ministry of Transportation, 1990

When the length of coastline is normalized by the land area and population, however, Korea's coastline per unit land area is much higher than that of Japan and the coastline per unit population is similar to those of Japan and the U.S. (Table 2). These measures imply the potential value and importance of coastal area to the lives of Korean people.

Table 2

Comparison of Coastline with other Countries

Country	Coastline (km)	Coastline per unit land area (km/1000 sq. km)	Coastline per unit population (km/million)
Korea	12,789	132	299
U.S.A.	56,700	6	270
Japan	33,057	88	304
England	8,850	36	158
France	7,820	14	150
Italy	5,050	17	92
Denmark	6,450	150	1,284
Netherlands	1,450	35	108

Source: National Physical Plan of Japan, 1973

Historically, despite this enormous coastal extension, Koreans have been mostly agrarian, not sea-going peoples. Although the seas around the Korean Peninsula have been extraordinarily rich in various economically useful species, fishing had been done only very casually by the early 20th century (described by A. Hamilton in 1904).[9] This might be partially due to the natural adversities of the Korean coast, which has limited locations for port development. On the west coast, there are obstacles to port construction such as the large tidal range, rushing tidal currents and dangerous shipping channels with their overabundance of reefs, shifting sandbanks, shoals, small islands and foggy days. The east coast is cut off from the interior by the Hamgyong and Taeback Ranges so that it is difficult to obtain a large enough hinterland for harbors, and the steep downward coast of the east side is also lacking in suitable bays. The tips of the bays of the south coast, in contrast, are filled for the most part with tidal flats.

With the opening of the country at the turn of the 20th century, marine-oriented activities in coastal areas increased, through encounters with foreigners and by the influence of Japan, and many harbors were developed for trading and fishing on the west coast. Important fishing species recorded in that time include sardines, mackerel, shark, red sea bream, corvina, anchovy, varieties of tuna, Alaska pollock, Pacific herring, halibut, etc. Mariculture was introduced by the Japanese on the south coast of Korea during Japanese colonial times. Laver and oysters were the most important cultivated species.

Since then, throughout the 20th century, the coastal area of Korea has undertaken a very dramatic level of change following the political and economic fates of the country. After the Korean war (1950-1953), national efforts to escape from the "absolute poverty" have brought enormous "black chimneys," symbols of economic development, on coastal land, and a substantial amount of coastal area has been reclaimed for agricultural and industrial purposes.

At this, the turning point of the 21st century, with apparently outstanding levels of economic development, there emerge concerns about the way the Korean coastal area is used, recognizing the conflicts among competing uses and the problems resulting from the misuses and abuses of coastal resources.

Thus, the objectives of our study are to identify major patterns of coastal use and the associated conflicts or problems, to analyze the legal and administrative basis for each coastal use, to determine important factors underlying the patterns of coastal use, and to define the stage that Korea has reached in the evolution of coastal zone management.

The landward boundary of the coastal zone in this study was defined by using existing administrative subdivisions such as the cities and towns adjacent to coastal water, mainly because most basic data for statistical analysis have been collected and compiled by administrative units. The seaward area of the coastal zone in this study extends 3 nautical miles offshore, where most coastal activities occur. This seaward boundary covers coastal waters of 53,000 sq. km, with 56% in the west coast, 36% in the south coast, and 8% in the east coast.[3]

COASTAL USES AND ASSOCIATED CONFLICTS AND PROBLEMS

Population Density and Distribution in Coastal Land

A total population of approximately 18 million inhabits coastal land of 32,000 sq. km. The population density of coastal land, 578 individuals per sq. km, is slightly higher than that of the nation, 441 ind./sq.km. Population distribution among coastal cities and towns in 8 provinces and Pusan, a special city, is illustrated in Table 3.[3,4] Population density ranges from 190 to 6,651 ind./sq.km, with the lowest in Kyongbuk and Kangwon provinces, located in the eastern part of Korea, the highest in Pusan city, in the southeastern area, and the second highest in Kyonggi provinces, capital area. The mean annual growth rates of population during 1970 to 1980 are displayed in Table 3, showing that the higher positive growth rates were marked in Pusan, Kyonggi and Cheju provinces and the negative rates in Cheonnam and Cheonbuk provinces, the southwestern part of Korea. The differential distribution of population and different growth rate among provinces primarily reflect unbalanced regional development during that period. These factors, including the national policy on economic development, will be discussed more in detail later in this paper.

Table 3

Population Distribution in Coastal Land

Provinces	**1970** (1000 ind.)	**1980**	**Growth Rate (%)**	**Pop. Density (ind./sq.km)**
West Coast				
Kyonggi	2,707	3,850	3.6	1,421
Chungnam	2,861	2,956	0.3	851
Cheonbuk	2,432	2,329	-0.4	1,143
Cheonnam	2,595	2,312	-0.2	276
South Coast				
Kyongnam	1,938	2,112	0.9	415
Pusan City	1,881	2,880	5.5	6,651
Cheju	366	444	2.4	243
East Coast				
Kyongbuk	702	765	0.9	190
Kangwon	689	717	0.4	190
Total	16,171	18,365	1.3	578

Source: Ministry of Interior, Annual Statistics of Provinces, 1986

Fisheries and Mariculture

Seafoods account for about 60% of the protein source for the Korean people. The fishery industry employs 1.6% of the total population and adds $1.6 billion to GNP with exports of $1.7 billion.[8]

Fishery production, including coastal fisheries, distant water fisheries, and mariculture in Korea has increased rapidly over the past 20 years, from 637,000 MT in 1965 to 3,050,000 MT in 1985.[12]

Table 4 represents the temporal changes in production of each sector and in the relative contribution to total fishery production. The annual growth rate of total fishery production was 15.8% in 1970s, but dropped to 5.8% in 1980s. During 1965-1985, the relative proportion of coastal fisheries has decreased (87% to 48%) with rapid increase in the relative production of the distant water fishery (1% to 25%) and an increase in the contribution of mariculture production (12% to 25%). This increase in fishery production may reflect improvements made in fishing boats (motorization) and the technology of harvesting, storing, and communication.

Table 4

Trends in Fishery Production

Type of Fishery	Production (% of Total) 1965	1975 (1000 MT)	1985	Annual Growth Rate (%) 60's	70's	80's
Coastal	554 (87)	1,209 (57)	1,495 (48)	6.2	8.9	1.8
Distant Water	9 (1)	566 (27)	767 (25)	18.0	40.9	13.5
Mariculture	74 (12)	351 (16)	788 (25)	12.2	35.5	9.1
Total*	637	2,135	3,103	9.4	15.8	5.8

*Total production of fishery includes the production from inland fishing.

Source: Ministry of Agriculture, Forestry and Fisheries, Annual Statistics of Fishery, 1985

The productivity per unit fishing effort, however, has decreased about 30% from 1975 to 1980. Major species caught in coastal fishing have also changed, with a decreasing proportion of red seabream and yellow corvina and an increasing proportion of file fish, anchovy, sardine and mackerel of high catchability. Overfishing is the most significant problem in Korean fisheries. In 1986, approximately 3,000 cases of illegal takings were reported in coastal waters.

Most mariculture (94.5%) is conducted in the southern coastal waters.[4] Oysters, laver, and sea mustard comprises 84% of the total mariculture production. The low variety of cultivation species is one of the important problems in the Korean mariculture industry. Other problems include internal factors such as the densification of mariculture grounds because of illegal culture activities and difficulties in obtaining space for culture, and environmental factors such as aggravating water quality and the space loss and environmental impacts caused by reclamation. Water quality of mariculture grounds has been mostly affected by oil spills, eutrophication and red tides, and domestic and industrial waste disposal into coastal environment.[5,6] For example, compensations of approximately $13 million and $3 million were made for the loss of mariculture production caused by oil spills and waste disposal, respectively.[12]

Ports and Shipping

Ports in Korea are regarded as a strategically important part of the social infrastructure, so that port development has been mostly carried out by the central government. The importance of ports has been emphasized by the export-driven economic policy since the early 1970s. The shipping capacity of Korea was measured to be 7.3 million MT, fourteenth in the world in terms of tonnage.[13] Korea currently has 46 ports and 416 harbors.[3] Among them, Inchon port in the capital area and the ports of Pusan, Pohang and Ulsan on the southeastern coast, represent over 75% of Korea's foreign trade by tonnage. The total foreign trade, including export and import and domestic trade made by shipping in 1983, were estimated at 163 million MT, projected to increase to 401 million MT by 2001.[3] Governmental decisions on port expansion in Inchon, Mokpo, Pusan port and the development of new ports in Gunsan and Asan city were made to meet growing demand, especially for trade with China .[10]

Oil spills are the most serious issue related to shipping activities. During 1981-1987, a total of 1,356 cases of oil spills, discharging 6,899 kl, were reported. Oil spills have mostly been caused by accidents involving fishing boats (53% of total accidents), not oil tankers (8% of total accidents).[4] Economic losses due to oil spills estimated from 1982 to 1985 were $19 million.[1]

Reclamation

National efforts to achieve a self-sufficient food supply and the corresponding demand for space for agriculture caused the spatial alteration of coastal areas by reclamation. A total area of 410 sq. km has been reclaimed, mostly on the west coast (70%). The purpose of reclamation has been mostly agricultural, about 92%, while industrial and residential purposes comprise only 7% and 1%, respectively.[3,4,5] This trend, however, is expected to change in the next decade because of growing demand for industrial and residential space. According to the National Basic Plan for the Reclamation of 1991, the Korean government will invest approximately $16 million by 2001 to reclaim about 1,235 sq. km in 261 areas, of which 923 sq. km is now under construction in 78 areas, mostly on the west coast (98%). The area for reclamation in this plan represents 1% of the current national land area and 4% of total coastal land area. The reclaimed area is zoned for several purposes, including agriculture (65.1%), urbanization (20.3%), industry (11.3%), power plants (1.7%), and waste disposal (1.6%). The proportion of industrial and urban purposes has increased to 31.6%, and additionally it has been reported that some areas zoned for agriculture would be changed to industrial purposes. Despite the benefits from land expansion, the reclamation of coastal areas, which are important hatchery and nursery grounds for fishes and function as buffer zones between land and coastal waters, results in a number of conflicts with other traditional uses such as fishing and mariculture. In addition, severe impacts on the ecosystem of adjacent coastal waters are expected, although there is not enough scientific information to measure the degradation of the ecosystem.

Urbanization and Industrialization in Coastal Land

The urbanization of coastal area in Korea is closely associated with the process of modernization. During Japanese colonial times, coastal cities including Inchon, Gunsan and Mokpo on the west coast, Samcheonpo, Pusan, and Pohang on the southeastern coast were developed for Japanese purposes, exploitation of resources and invasion of the land.[4] After the end of the Second World War and the Korean War (1950-1953), many refugees settled in Pusan, Kangleung and Sokcho, and Jinhae was developed as a military-port city. Since launching the national economic development plan in 1961, Korea has experienced serious economic development which depends heavily on the export of goods and the import of foreign resources. With this background, rapid development of industrial sites occurred — in two port cities, Inchon and Pusan, which have large hinterlands, and also in Masan, Ulsan and Pohang, cities on the southeastern coast.

The pattern of economic activities in coastal cities varies depending on several factors such as transportation, relation with other central areas or natural characteristics, etc. Pusan city, for example, has various functions including fisheries, industry, transportation, trade, and recreation. In contrast, the major economic activities in Kwangyang city, which is on the south coast, are mostly industry and trade.

Since the 1960s, industrial complexes of large scale have been developed in the southeastern coastal area. Several factors, including heavy dependence on foreign resources (oil and minerals), convenience in trade and transportation, and marine-oriented industry, make this area a good site for industrialization. A total area of 249 sq. km is used by 1,923 companies for petrochemical, machinery, shipbuilding, ferrous, nonferrous, electronics, food, clothing, leather, fish processing industries, etc.[4]

Pollution is the most serious problem caused by industrial activities on coastal land. Public health problems resulting from polluted air and water have been reported in the Onsan and Ulsan industrial complexes since the mid-1980s. The most representative case is the eutrophication of coastal water caused by municipal and industrial effluents, and chronic red tides in Jinhae and Masan Bay. Fish and shellfish kills have been reported, and currently fishing and aquaculture are not allowed in that region.

Coastal Tourism, Recreation and Protected Areas

Swimming is the most popular coastal recreational activity in Korea, while boating and recreational fishing are much less popular than in western countries. The number of visitors to beaches on each coast was estimated from 1982 to 2001 in Table 5. In 1982, a total of approximately 16,000 people visited the beach for swimming, and the number of visitors is expected to increase about four times by 2001. The south coast is the most popular place for bathing, accommodating 47% of total visitors in 1982, and the proportion of visitors in the south coast is expected to increase up to 70% by 2001.

Table 5

Estimated Number of Visitors to Beach (1000 ind.)

	Number of Visitors (% of Total)			
Coast	**1982**	**1986**	**1991**	**2001**
West Coast	6,147	6,840	7,240	8,405
	(38)	(29)	(22)	(15)
South Coast	7,627	13,796	20,258	38,982
	(47)	(58)	(63)	(69)
East Coast	2,373	3,195	4,719	9,138
	(15)	(13)	(15)	(16)
Total	16,147	23,831	32,217	56,525

Source: Hong et al., 1985

To protect the natural beauty, wildlife and heritage in coastal areas as well as to attract people to tourism sites, national parks have been established since 1968 as the Natural Environment Preservation Zone, where construction, coastal structures, reclamation, mining, and fishing (except for mariculture) are not allowed. Table 6 shows the names of national parks, their areas and dates of legal protection. Korea has created a total of 2,900 sq. km of national parks in coastal land and waters.

Table 6

National Parks in Coastal Areas

Name	Land Area (sq. km)	Sea Area (sq. km)	Date
Hallyo Marine Park	129	350	1968.12.31
Byonsan Penninsual	53		1971.12. 3
Seosan Beach	39	290	1978.12.20
Donghae	9		1979. 6.22
Dado Marine Park	340	1,699	1981.12.23
Kyongpo	9		1982. 6.26
Total	579	2,339	

Source: Hong et al., 1985

In addition, the Fishery Resources Protection Zone of approximately 4,100 sq. km has also been created, where industry, reclamation, dredging and mining are not allowed. For coastal areas having severe pollution problems such as Masan and Jinhae Bay, Areas of Special Control on Coastal Pollution have been designated, where fishing, aquaculture, reclamation, construction, dredging and toxic waste disposal are prohibited.[34]

Waste Disposal

Industrial and municipal effluents have been directly discharged into coastal waters or indirectly discharged through runoff from land. A total of 4,237 companies discharged industrial effluents of 450 thousand tons daily in 1988.[2] The total capacity of treatment systems of industrial effluents is 155 thousand tons per day. Thus, even if the system is fully operated, only 34% of effluents can be treated before disposal. Similarly, only 25% of total municipal effluents is treated before disposal by a total of 16 treatment plants. Disposal of untreated effluents has introduced substantial amounts of organic material and other pollutants into the coastal environment. For example, in Inchon city, one of the heaviest polluting cities, the daily load of organic material measured as Chemical Oxygen Demand

(COD) into adjacent coastal water was 73 tons in 1984, expected to double to 164 tons by 2001.[2] Table 7 represents the regulatory levels of coastal water quality.

Table 7

Standard for Coastal Water Quality

Level	pH	COD (mg/1)	DO (%saturation)	Total -N (mg/1)	Total -P
I	7.8 ~ 8.3	<1	>95	<0.05	<0.075
II	6.5 ~ 8.5	<2	>85	<0.1	<0.015
III	6.5 ~ 8.5	<4	>80	<0.2	<0.03

COD: Chemical Oxygen demand DO: Dissolved Oxygen

Source: Ministry of Environment, 1990

According to these levels, there are three categories for defining coastal water quality. The first category includes water suitable for fishing and mariculture; the second suitable only for swimming or recreation, not for fishing; the third suitable only for industrial or port uses. The mean COD levels of major coastal waters measured during 1986-1990 are illustrated in Figure 2. Most of the waters observed on the west coast are suitable only for industrial use, and class I water suitable for fishing is found nowhere.[1]

According to the national long-term plan (1991-1995) for environmental preservation developed by the Ministry of Environment, a total investment of about $106 million, less than 1% (0.7%) of total funding for the environment, has been allocated to remedy marine pollution. Seventy percent of the funding will be used to clean up Chungchoho of Sokcho city, a lagoon with a very low rate of sea water exchange. The sediment in this area has been severely polluted by various wastes, including organic waste from the fish processing industry. COD of this coastal water marked over 10 mg/L in 1990. Another 17% of the funding will be used to dredge the contaminated sediment from Masan bay, which has chronic red tide problems.

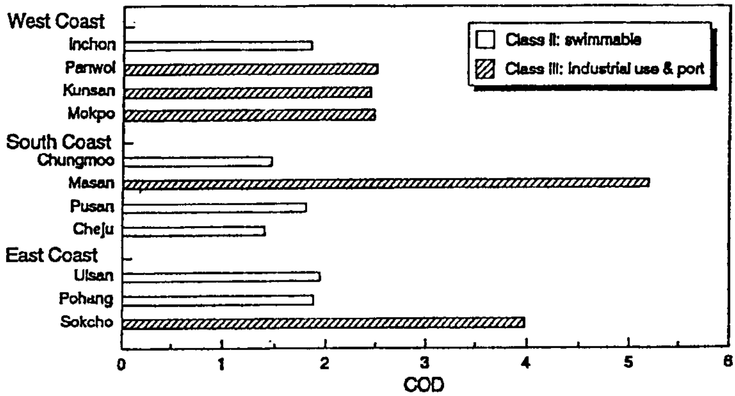

Figure 1. The mean level of COD (mg/L) observed in major coastal waters during 1986-1990
Source: Ministry of Environment, 1991

LEGAL AND ADMINISTRATIVE ASPECTS

The main objective of this section is to describe the legal and administrative system with regard to the use of coastal area and to identify critical problems in terms of coastal area management.

In Korea, there is no legally defined boundary of the coastal zone. Instead, coastal land is managed as a part of the land according to the National Land Use Plan. Generally, the pattern of land use is determined by the Ministry of Construction by means of zoning. There are ten categories of zone characterizing land use: urban (13.5% of total land area), residential (0.8%), agriculture (24.9%), forestry protection (47.6%), industry (0.1%), natural environment preservation (6.2%), recreation and tourism (0.2%), fishing resources preservation (4.3%), development promotion (2.4%) and reserved zones. The coastal waters of Korea are owned by the nation and regulated by the State-owned Water Area Management Act of 1961 (Law No. 848), and the water adjacent to ports and harbors is managed by the Port Act of 1967 (Law No. 1941) and the Harbor Act of 1969 (Law No. 2106), respectively.

Many different laws and regulations are involved in regulating the activities in coastal areas. A total of thirty-eight acts have direct or indirect relevance to coastal activities including the utilization of natural resources, the development of industrial or urban areas, and the preservation of the natural environment. Legislation can be categorized into three types: land-concerned laws (19), marine-concerned laws (15) and coast-concerned laws (4). Figure 2 shows the various acts which play a major role in each functional area.

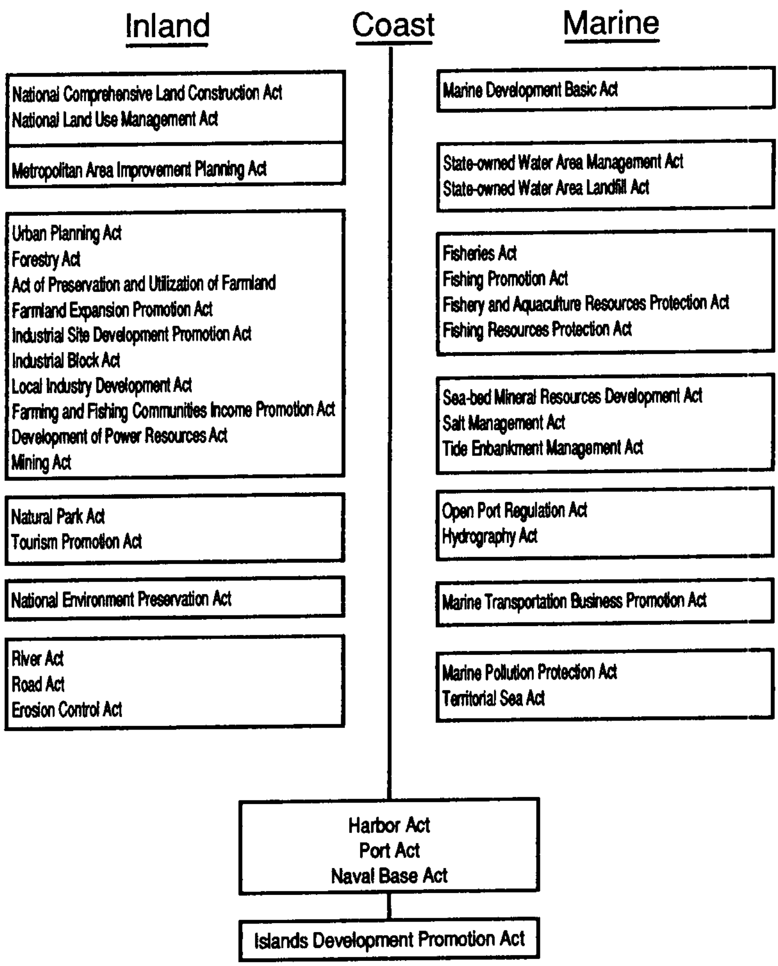

Figure 2. Legal basis for coastal zone management in Korea

Source: Ministry of Construction, Coastal Preservation and Use Plan, 1989

Similar to the complicated legal system, several ministries and agencies are engaged in managing and regulating coastal areas. They have their own functions and responsibilities based on related laws and regulations. Basically, the decision-making regarding matters of the coastal area is distributed among eleven central government bodies. In addition, certain provincial governors and a few large city mayors, such as those of Pusan and Inchon city, have been delegated either consultative or special authority. The Ministry of Construction has exerted the most powerful influence in the policy-making process. Table 8 shows the ministries and government agencies which are in charge of the activities occurring in coastal areas, the functional area that they cover, and the acts concerned.

Table 8

Korean Governance in Coastal Area Management

Category	Activity	Legislation
Ministry of Home Affairs	• Prevent marine pollution • Establish islands development plan	• Marine Pollution Prevention Act • Islands Development Promotion Act
Ministry of National Defense	• Manage naval base	• Naval Base Act
Ministry of Agriculture, Forestry and Fisheries	• Landfill for farmland expansion • Establish & manage tide embankment	• Farmland Expansion Promotion Act • Tide Embankment Management Act
Fisheries Administration	• Establish fishery policy • Give fishery license • Designate fishing resources protection area • Designate & manage harbor	• Fisheries Act • Fishing Resources Protection Act • Harbor Act
Ministry of Trade & Industry	• Arrange industrial site • Manage salinity	• Industry Block Act • Salt Management Act
Ministry of Energy & Resources	• Develop marine mineral resources • Develop power resources	• Mining Act • Sea-bed Mineral Resour-ces Develoment Act • Develoment of Power Resources Act
Ministry of Construction	• Establish comprehensive plan for national land construction • Establish national land use plan • Manage state-owned water area	• Comprehensive Plan for National Land Construction Act • National Land Use Planning Act • State-owned Water Area Management Act

Ministry of Construction (continued)	• Reclaim state-owned water area • Designate & manage marine park	• State-owned Water Area Landfill Act • Natural Park Act
Ministry of Environment	• Establish environment policy • Review environment impact statement • Prevent marine pollution • Designate & manage the area of special control on coastal pollution	• National Environment Preservation Act • Marine Pollution Prevention Act
Ministry of Transportation	• Designate & manage marine resort area • Hydrographic survey	• Tourism Promotion Act • Hydrography Act
Maritime & Port Administration	• Designate & manage port • Promote coastal transportation	• Port Act • Marine Transportation Business Promotion Act
Ministry of Science & Technology	• Establish marine development policy • Establish marine development basic plan	• Marine Development Basic Act
Provincial Governor	• Establish provincial Land use plan • Give coastal fishery license • Manage the second level harbor	• Comprehensive Plan for National Land Construction Act • Fisheries Act

Source: Hong et al., 1987

As stated above, Korea's coastal area is under the jurisdiction of many sectionalized ministries and agencies which get their authority from numerous national-level laws. And the coastal area has been managed under the development-oriented national policy. Under these circumstances, several concerns have been addressed in managing the coastal area as an integrated socioeconomic system.

The most critical problem is the fact that Korea does not have any device to coordinate and solve the conflicts among the ministries and agencies which drive their own coastal programs. The Ministry of Construction is in charge of major parts of the national land use plan, especially development-oriented plan, whereas the Ministry of Environment and the Fishery Administration are responsible for the preservation of the coastal environment and fishing grounds. These ministries often disagree with each other regarding certain coastal activities such as reclamation.

Secondly, with strong centralization of the governance system, all major policy decisions in Korea are formalized at the level of central government and flow down from there through the provincial and local governments to the people. Therefore, public involvement in all sectors of decision-making, including matters of coastal area, is seriously limited.

Finally, the failure of the nation to perceive the coastal environment as a critically important national resource has resulted in the lack of management of coastal areas. The major drawback of the Korean policy on environment preservation is that the policy is post-remedial rather than preventive.

It was not until the mid-1980s that the Korean government gave due attention to coastal problems. Recently, the Ministry of Construction and the Ministry of Science and Technology have made some efforts to improve the legal and management system of coastal zone, including consideration of the enactment of national legislation which enables the Korean government to manage the coastal zone comprehensively. Two alternatives are under discussion — enactment of the Coastal Management Act and the amendment of existing laws such as the National Land Use Planning Act or the State-owned Water Area Management Act.[6,7]

IMPORTANT FACTORS DETERMINING THE PATTERN OF COASTAL USES

The mechanisms underlying the historical alteration of coastal uses can be identified by understanding the dynamics of two interactive forces, development versus conservation. There are three important components to be considered in determining the dynamics between development and conservation: Governmental policy and expenditure, industrial investment, and public awareness or complaints. The force of each component relative to others in determining the national policy depends on the political and socio-economic backgrounds of a country.

Since 1962, the central government of Korea has played the most significant role in leading our economy, with the establishment of the first five-year plan of national economic development. The important aspects in terms of coastal develoment during the first and the second development stages (1962-1971), which are defined as the phase of labor-intensive and export-drive light industry, include the reclamation of the Yeongsan river area to enhance the agricultural production and the establishment of Free Export Zone at Masan to promote exports.[10] At this phase, the governmental and industrial expenditures on environmental conservation were virtually negligible, and there was no significant level of public awareness of environment problems.

During the third and the fourth phases of economic development (1972-1981), which are characterized by the export-driven heavy and chemical industry, the reclamation of coastal area was continued mostly for agricultural purposes. The creation of large scale industrial complexes on the southeastern coast was also carried out at this stage.[10] The center of the shipbuilding industry was constructed in Ulsan as the first industrial complexes of Korea. The largest industrial site, the Changwon Integrated Machinery Complex, was established between Masan and Jinhae. Petrochemical complexes were established in Pohang on the east coast. Since economic growth was an indisputable goal to be achieved at any cost in the early 1970s, no significant consideration was given to environmental protection. Moreover, so-called "pollution industries" were accepted from foreign developed countries, which had conflicts and difficulties operatng them in their countries because of pollution problems. When the rapid concentrations of heavy industry and population caused pollution problems, complaints from the public sector began to increase. With this background, the National Environment Preservation Act and the Marine Pollution Prevention Act were legislated in 1977, and the Environment Administration was created under the Ministry of Health and Social Affairs in 1980. There is little evidence, however, that these laws were taken seriously by the Korean government and industry at that phase.[14]

In 1986, the Environment Administration was expanded, and reorganized environmental protection programs, including the implementation of a comprehensive survey of pollution and natural resources.[11] The Environmental Impact Statement (EIS) became a prerequisite to 11 kinds of large-scale public projects. In 1987, the EIS requirement was expanded to private projects, and the enterprises responded by setting up environment sections and hiring environmental experts. However, the overall responses from government officials and private enterpreneurs were not so positive in the 1980s. The environment was still given a low-priority in every level of the decision-making process.

The national economic development plan of Korea put more emphasis on efficient economic growth until the 1980s; however, the national goal in economic development was readjusted to ensure harmony between growth and welfare as well as more balanced regional development. In this context, the West Coast Development Plan emerged in 1986.[10] In addition to the goal of stimulating the less developed western part of Korea to achieve more balanced regional development, the abundant supply of land resources by reclamation was an important internal factor in establishing the plan. The main parts of the West Coast Development Plan include the reclamation of the Si-Hwa area, the creation of large industrial complexes, the expansion of transportation networks, and port expansion and the development of new ports (Figure 2).[10]

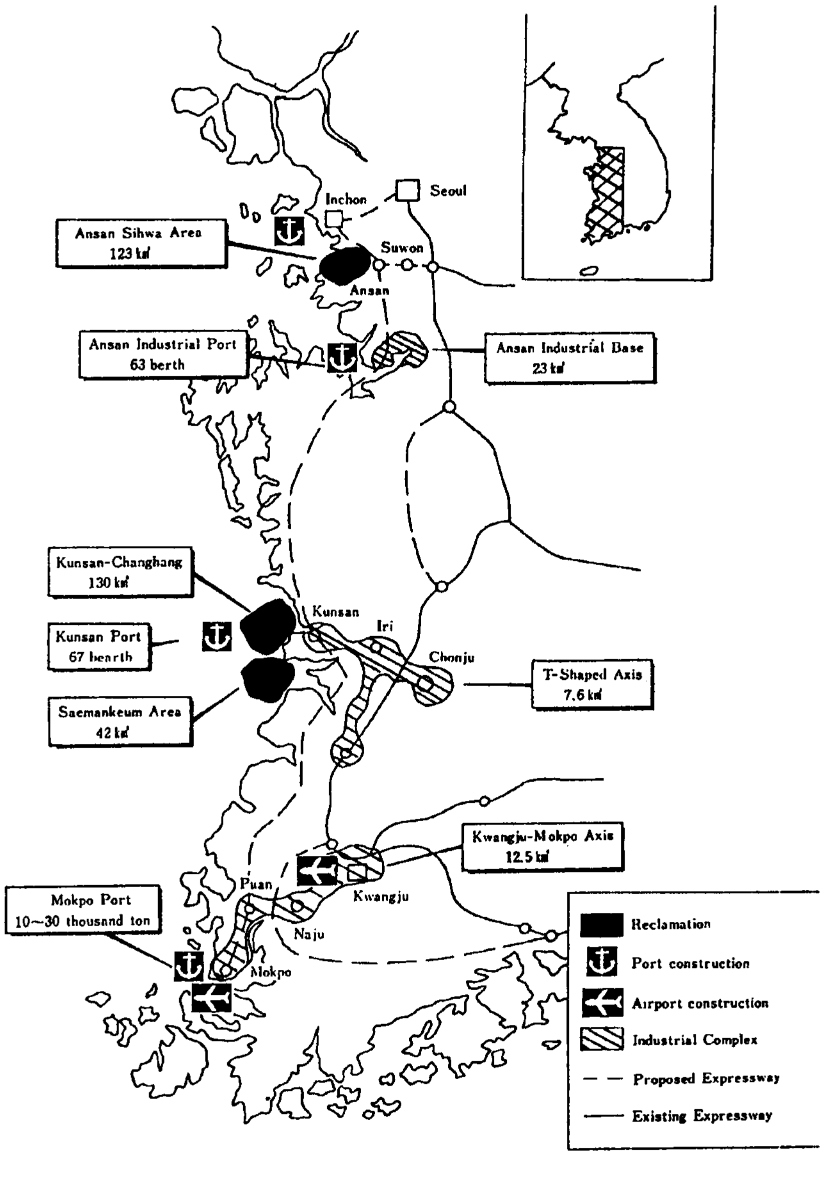

Figure 3. Plan for the west coastal development

Source: Ministry of Construction, 1986

As one effort of the Korean government to minimize the inefficiency and redundancy of marine-oriented administrative works, the Marine Development Basic Act was enacted in December of 1987, and the Marine Development Council was created to formulate national policy on ocean develoment.

Another important political factor which may affect the pattern of coastal uses is the start of a system of local autonomy in 1991. Although this political system can lead to more active public participation in decision-making processes, some pessimistic concerns were raised that this might accelerate the blind pursuit of development policies without due consideration of the carrying capacity of the environment, under the catchphrase of "regional development."[11]

These potential problems related to development-oriented policies should be controlled under the comprehensive national policy on the environment. The Environment Administration was upgraded to the Ministry of Environment (ME) in January, 1990. The ME proclaimed the year 1990 as the first year of environmental protection and pledged to give high priority to the preservation of a clean and livable environment. The total expenditure on environmental conservation, scattered among various ministries, amounted to $250 million in 1988, 0.2% of GNP. According to the long-term environmental preservation plan, the government will spend $24 billion until 2001, when the environmental expenditure would be equivalent to 1% of GNP. Major spending will be given to the construction of sewage treatment plants, increasing the treatment capacity from 25% in 1988 to 65% in 1996. This effort should lead to some improvement in at least point-source pollution in coastal waters.

PROSPECTS FOR COASTAL ZONE MANAGEMENT IN KOREA

The coastal zone of Korea has experienced many changes in the past three decades, in which the government's will for economic development has been the most influential factor. The lack of knowledge of the fragility of coastal ecosystems on the part of decision makers, the low-priority of environmental conservation to the Korean government and industries, and low public awareness have caused numerous conflicts among different coastal uses along with serious environmental problems. With the recognition of these critical issues, the urgent need for a comprehensive management program for the Korean coastal zone has been suggested by scholars and the government from the mid-1980s. Since 1984, the Ministry of Construction and the Ministry of Science and Technology have supported some research by the Korea Ocean Research and Development Institute (KORDI) and the Korea Research Institute for Human Settlements to undertake a series of investigations on coastal zone management issues. The main objectives of the research were to identify the status of coastal uses and the natural environment, to determine the areas of conflict and pollution, and to suggest policy direction to formulate a comprehensive management program for the coastal zone.

The most critical problem in establishing a coastal management program in Korea includes the lack of experts and information to operate the program. Currently, KORDI is conducting a long-term project to establish a data base system for the coastal zone.

Looking toward the 21st century, the government has expressed a strong will for environmental conservation, and industries have started to invest in pollution control, recognizing that they cannot survive economically any longer if they persist in neglecting public complaints about environmental problems. Under these social circumstances, consideration of the enactment of laws regarding coastal zone management suggests positive prospects for the development of an ecologically sound and economically viable coastal zone program in Korea.

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Developments in Coastal Ocean Space

9

Ocean Space Utilization: Technology Trends and Future Concepts

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ABSTRACT

Coastal ocean space development has long been the focus of attention for seafaring nations and is growing in importance and interests to a coastal-minded society. The emphasis is on ocean space development for economic gain and societal benefit in harmony with the environment. To assess trends in planning and developing offshore facilities, over 400 projects were reviewed for the 30-year period between 1961 and 1990. Of these, 50 projects were further divided into facilities for production and urban residential/amenity assistance. Future emphasis will be towards integrated multiple-user/multiple-function offshore complexes focusing on an information-oriented, high-tech global marketplace.

INTRODUCTION

The wise use of coastal ocean space in harmony with the environment to meet the burgeoning needs of a coastal-minded society is a major goal as we enter the 21st century. The coastal regions of ocean-bounded nations are developing rapidly, and some are doing so in an unplanned manner and without serious concern for the environment or quality of living. Since the industrial revolution, industrialized nations focused mainly on economic wealth, allowing the vastness of the land, ocean, and air environment to accept and defuse many insults to the environment. Now the people of industrialized nations are placing great value on the quality of the environment and living a better life.

International Perspectives on Coastal Ocean Space Utilization
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Some environmental damage has already been done to coastal regions in the form of marine pollution, coastal erosion, and coastal smog; and to the global environment in the form of global warming and ozone depletion. Environmental programs have begun measuring, monitoring, and assessing environmental health; steps are being taken to stop further pollution and reverse the impacts; and new developments are expected to carefully consider potential impacts to the environment. Besides the present state of the environment, the population has also been growing exponentially over the last 40 years and is expected to almost double over the next 40 years, from over 5 billion to about 9 billion. This steady increase equates to less land per person, doubling the need for food, potable water, energy, and material resources and a potential increase in environmental impact. Population growth continues to increase more rapidly in the coastal region where 50 percent of the population and industry lives within 50 miles of the coast and is expected to increase to 75 percent by the year 2000. In Japan, the figure is closer to 70 percent because of their relatively uninhabitable mountainous terrain. Even though inland space may be available in the U.S. and in some prefectures in Japan, the need to provide more coastal space for the coastal-oriented public seeking spatial openness, the coastal view, fresher air, marine recreation, and other social amenities of well integrated coastal communities is steadily increasing.

In Japan, the need for additional coastal real estate has resulted in developing artificial islands in estuaries and coastal areas for a variety of dedicated uses such as power stations; a new municipal airport; and integrated, high-quality living, working, educational, and recreational facilities. In Japan, major coastal development projects have been completed and others are under way and planned in major coastal areas including Tokyo, Yokohama, and Kobe-Osaka regions. In the U.S., several major port and harbor communities such as Los Angeles, Long Beach, Baltimore, and New York have begun or are planning large-scale coastal ocean space revitalization projects.

In order to assess trends in planning and development of offshore facilities, over 400 projects were identified in the literature for the 30-year period between 1961 and 1990. Of these, 50 projects were further divided into facilities for production, urban residential, and urban amenity assistance.

Future trends in coastal development include: port and harbor modernization and waterfront development; integrated living, working, and recreational facilities; a seaward extension of land-based facilities, artificial islands, and floating facilities and cities; and hybrid combinations of fixed and floating structures or partially buoyant structures.

ENVIRONMENTAL CONSIDERATIONS

The coastal environment is being impacted by slow natural processes punctuated by occasional natural disasters and human-induced impacts that appear to cause faster change. The slow geophysical natural processes have a profound impact usually dealing with time scales of centuries; however, occasional natural disasters such as earthquakes, tornadoes, and hurricanes are major forces that greatly impact coastal living and have significant implications in urban planning and structural design. Besides natural disasters, man-induced disasters exist such as global warming, ozone depletion, acid rain, and marine pollution. The significance of these on coastal ocean space utilization (COSU) is briefly described below.

Natural Disasters

Earthquakes have had a major impact all around the world. The Pacific rim countries and especially major coastal cities are located on the rift zones of the "ring of fire." Earthquake engineering has advanced structural designs to provide a high degree of shock mitigation for buildings on land. Construction of artificial islands on rift zones would be obviously avoided; the effect of tremors would depend on the degree of direct coupling and how much would be isolated by layers of sediment and the magnitude of the shearing lateral forces. Floating facilities would have the added advantages of using the water as a buffer; however, an artificial island or floating facility near shore would require a design consideration for a tsunami which could be the result of an earthquake or coastal avalanche. Historic environmental data on earthquakes and tsunamis would normally be consulted in making a site selection and estimating the environmental forces involved. Similarly, historic data on typhoons and hurricane tracks and tornado paths are needed in the site selection process to consider those forces in structural design and protection of property. In regard to tornadoes, Doppler radar can provide as much as 30 minutes warning to permit people to seek appropriate shelter. Regarding the protection of human life against hurricane disaster, hurricane tracking radar and observation techniques provide early warning. In the U.S., all of the coastal basins of the East Coast and Gulf of Mexico have been modeled using computer techniques to predict hurricane landfall and the level and extent of storm surge. This provides a more localized warning to enable residents to evacuate and move in the right direction.

Many coastal cities in the U.S. and Japan are vulnerable to high magnitude typhoons and hurricanes. For example, in the U.S. over 20 years ago, Hurricane CAMILLE was the first category five hurricane in 40 years to hit a coastal city, resulting in very severe losses (256 lives and $1.5 billion) in 1969. Since then, many new coastal communities are located near shore at sea level and some on reclaimed land. Most of these low-lying communities are vulnerable to the devastating effects of powerful winds and storm surges. A storm surge from a category five hurricane striking the coast would be truly devastating for these coastal communities.

Global Warming

The phenomenon of global warming over the past century has been attributed to atmospheric accumulation of greenhouse gases such as carbon dioxide and methane, which act like a blanket to trap the sun's radiant heat. Greenhouse gases are produced by all forms of combustion, especially by automobiles, power generation, and the burning of wood in clearing forested land such as the Amazon Rain Forest. The environment's ability to assimilate carbon dioxide is being reduced because expanding urban development, deforestation, and destruction of rain forests increase the losses of trees and vegetation — the natural assimilators of carbon dioxide. The processes and capacity of our oceans to assimilate or release carbon dioxide is not well known at this time. Though exact figures cannot be predicted, the general consensus is that global warming will increase and produce deleterious effects impacting agriculture, causing sea-level rise, and affecting quality of life while society adjusts to its effects.

A consensus of researchers agrees that the Earth, on average, has warmed about 1°F over the past century. If CO_2 levels double by the middle of the next century, average global temperatures may increase several more degrees. The resultant warming will not be uniform over the Earth — least in the tropics and greatest at the poles where it would melt some of the polar ice caps. The melted ice, most of which is now on land, and the thermal expansion of the oceans would cause global sea levels to rise 30 to 60 centimeters (cm). Scientists continue to debate the exact magnitude and timing of worldwide warming.

The 1980s were the warmest decade in the last century and 1990 was one of the warmest years on record. Warming of the seas has already caused environmental degradation of coral reefs around the world. As the sea warms up, the coral polyps that build the reefs with their skeletal remains stop feeding on micro-algae and become weak and die; then the reefs lose their red, yellow, and golden hues, leaving the coral with a bleached look. These reefs can serve as early warning indicators of global warming of the seas.

Over the past 50 years, global sea levels have been rising at about 3.0 millimeters a year (three times the rate of the previous 50 years). If this trend continues or possibly escalates, sea levels could rise as much as 30 to 60 cm by the middle of the 21st Century, flooding some coastal cities and villages. This will create a concern in designing and constructing homes, buildings, ports, and harbors for future coastal communities.

Technology plays a vital role in providing a wide variety of atmospheric and ocean measurement systems and large-scale networks to monitor the effects of global warming; conservation measures to reduce consumption of fossil fuels; a means to reduce CO_2 emissions; alternate fuels for transportation; alternate energy sources to supply electrical power; a means to redeem CO_2; and new water supplies to offset scarcity due to warming.

Sea-level rise is a major concern for coastal urban planning and structural design. A global sea-level measurement network is in place and can be referenced to a Very Long Base Interferometer (VLBI) System for obtaining absolute water-level measurements on the order of 1 cm. There are 16 VLBI stations worldwide that establish accurate geodetic references which are coupled to the Global Positioning System (GPS) satellite network for absolute water-level accuracy worldwide. Such absolute accuracy will enable determining whether the sea level is rising, or the land is subsiding or eroding. This is important information for coastal planners.

Marine Pollution

Regarding marine pollution, finite limits are being reached in many coastal areas, as highlighted by beach closings, prohibitions on shellfishing, habitat losses, and health warnings to seafood consumers. Many coastal regions around the world, especially near major population centers, have reached critical stages of marine pollution due to sewer outfalls, ocean dumping, land runoff, shipping discharges, and plastic debris from marine recreational activities and marine vessels. In addition, industrial waste and effluents are being discharged in coastal waters, and in rivers and streams that terminate in coastal estuaries. Hazardous material spills, especially those that occur in coastal waters and within the Exclusive Economic Zone (EEZ), are a major polluting concern. Major oil spills such as the EXXON VALDEZ (spilling 11 million gallons) and the AMOCO CADIZ (spilling 60 million gallons) provide documented results of the damaging effects on marine life, marine habitat, beaches, wetlands, and on the economy and quality of life in coastal communities.

Many marine instrumentation systems are used to sample, measure, and analyze water-quality, marine sediments, and marine life for pollutants. A major program under way at the National Oceanic and Atmospheric Administration (NOAA) over the past 6 years is the National Status and Trends Program. This program involves sampling bottom fish, shellfish, and sediments at about 300 sites in coastal waters around the United States; making laboratory measurements of over 70 chemical contaminants in sediments, fish livers, and bivalves; and analyzing annual measurements for year-to-year comparisons to determine the status and trends in pollutant levels. Based on 6 years of measurements, the highest concentrations of both trace elements and organic contaminants were found near major coastal cities of Boston, New York, San Diego, Los Angeles, and Seattle.

Coastal Data and Information

Most of the developed nations have various data collection, processing, assessment, dissemination systems, and archival centers holding the kinds of environmental information identified in the previous sections. The scope, extent, quality, and accessibility of this data differ in each nation. In the U.S., major efforts have been undertaken to access all available sources of data and information taken in the past and present, especially in the coastal ocean and EEZ. This information is electronically stored, processed, and analyzed using desk-top computer systems. More of the data is being entered and accessed, using the Geographic Information System (GIS). Also, the data is compiled in atlases, covering all of the U.S. coastal regions out to the limits of the EEZ. Using this type of data and information is essential to decision-makers involved in all aspects of coastal ocean space development and utilization.

Environmental Impact of Structures

Marine structures can be largely divided into several types (i.e., floating, fixed, gravity, and reclaimed land types). The degree of their impact on the ocean environment (ecology, climate, and physical characteristics) varies from major, in the case of reclaimed land structures, to light, in the case of a semisubmersible platform. The impact of a structure on the ocean environment is largely determined by the degree of free flow of seawater (including content of dissolved oxygen, nutrients, and any imparted temperature change); the degree of sunlight penetrability to stimulate photosynthesis and carbon dioxide assimilation; and the rate of evaporation (affected by atmospheric and water temperatures). In general, the impact is likely to increase with a larger ocean space coverage area of a structure.

Regardless of its type and size, a structure's use objectives and assigned functions can have a severe impact on the ocean environment. If a structure is intended solely as living space, the impact is relatively small. In comparison, the potential impact is very large in the case of a desalination plant, an OTEC (Ocean Thermal Energy Conversion) project, or a nuclear/coal/oil thermal power generation plant which directly uses very large volumes of seawater as a heat exchange medium. Furthermore, a petrochemical plant, chemical plant, or a heavy machinery manufacturing plant which produces contaminant industrial waste may cause as much damage as the above.

In considering technical issues relating to ocean control, calm and safe ocean space must be secured to protect and also promote the effective use of the ocean space. Technologies to control high tides, tsunami, and swell are very much localized at present and require urgent development of technologies to safely stabilize and control extensive ocean space.

Ocean Space Development in Harmony with the Environment

Based on these environmental considerations, guidelines for future coastal ocean space development include:

• Site selection and development for economic gain in balance with the ecological needs of society.

• Avoidance of sites prone to damage by natural hazards, and design considerations which protect against serious damage due to hurricanes, typhoons, and storm surges.

• Minimize alteration of the natural environment. Preference for structures which reduce alteration to natural circulation, temperature, and chemical constituents of the body of water intruded.

- Avoidance of hydrocarbon fuel combustion by using alternate fuels relatively free of pollutants for electric power plants and transportation systems.
- Energy alternatives including solar and solar-derived ocean energy systems; advanced safe nuclear power systems including future development of nuclear fusion; and conversion to hydrogen for a clean-fuel economy.
- Municipal waste management systems based on recycling waste materials and clean incineration of toxic wastes within acceptable standards.
- Special handling and storage of toxic materials and treatment facilities to neutralize wastes.
- Incineration at sea within acceptable standards and possible use of fly ash for manufacturing environmentally safe building materials.
- Ocean energy conversion for electrical energy and other cost-effective products such as freshwater and nutrients for aquaculture.
- Artificial upwelling systems that stimulate photosynthesis for open-ocean ranching and controlled absorption of atmospheric CO_2.
- Environmental monitoring systems that periodically monitor environmental parameters that are indicators of environmental health.

EVOLUTION OF OCEAN SPACE DEVELOPMENT PROJECTS

A total of 402 ocean space development projects were identified in the literature for the period between 1961 and 1990. These included completed development projects, those previously planned and proposed, and those currently underway or planned. In the case of planned projects, only those which have been determined to be technically feasible through engineering analysis (excluding financial factors) were selected. These projects are classified in Table 1 in terms of their functional characteristics (production, recreation, urban and residential space, transportation/communication, safety/disaster prevention/national land conservation, and others) and resource characteristics (biological, mineral, seawater, and ocean energy and space such as coastal or offshore development). The classification results show that production facilities are the top category in terms of function, followed by transportation-related facilities. In terms of resource development, mineral and seawater resources are first, followed by offshore space development projects. Fifty projects were selected based on the criteria that they are ocean space utilization projects for the benefit of society and not just coastal land reclamation projects. These 50 projects were further divided into production facilities (industrial production base, oil and gas storage, and production base), urban amenity assistance facilities (power generation plant, airport, recreation facility), and urban residential facilities (marine city). Their structural types (reclaimed land type, gravity type, fixed type and floating type) and physical characteristics (in terms of distance from the nearest coast, sea depth, location and space coverage area), graphically illustrated in Figures 1 through 6, were compared and the following observations can be made.

Table 1

Ocean Space Development Projects

Project Name	Country	Plan (P) Constr (C)	Area (ha)	Dist (km)	Depth (m)	Structure Type
Industrial Use						
Nagova-Port No. 9	Japan	1961-C	218	2	3	Reclam
Yokohama Honmoku Port	Japan	1963-C	594	2.5	12	Reclam
Yokkaichi Kasumigaura	Japan	1967-C	387	0.1	12	Reclam
OogishimaArtificial Is.	Japan	1971-C	515	0.4	15	Reclam
Osaka North Port	Japan	1972-C	615	0.5	10	Reclam
Industrial Is. in the North Sea	NLD	1973-P	50	50	25	Reclam
Multipurpose Offshore Industrial-Port Is.	USA	1975-P	728	13	18	Reclam
Akita-Wan Artificial Is.	Japan	1982-P	780	7	35	Reclam/ Pile/Jacket
Shimonoseki Kitaura	Japan	1984-P	750	1.0	30	Reclam
Oil-Gas Development						
Thums Island	USA	1965-C	16	2	12	Reclam
Ubarana Concrete Platform	Brazil	1967-C	0.2	12	15	Gravity
Roberts Bank Development	Canada	1968-P	90	4.8	21	Reclam
Porto de Areia Blanca	Brazil	1973-C	1.8	1.4	7	Reclam
Namorado Platform	Brazil	1973-C	0.3	90	146	Pile/Jacket
Fisherman Island	Australia	1977-C	600	0.7	0	Reclam
Statford Platform	Norway	1980-C	1.3	150	145	Gravity
Tarsiut Island	Canada	1981-C	1	40	22	Reclam
Shirashima Floating Oil Storage	Japan	1986-C	60	8	4	Float
Power Plants						
Bolsa Island Project	USA	1970-P	15	1	20	Reclam
Atlantic Generating Sta	USA	1970-P	75	4.8	17	Float
Offshore Coal Pwr Plant	Japan	1980-P	120	7	25	Reclam
Floating Is.– Coal Power Plant	Japan	1980-P	2.25	30	100	Float
Nuclear Power Plant	Japan	1980-P	2.96	5	100	Float
Gobou Power Plant	Japan	1980-C	35	0.2	18	Reclam

Table 1 (continued)

Ocean Space Development Projects

Project Name	Country	Plan (P) Constr (C)	Area (ha)	Dist (km)	Depth (m)	Structure Type
Airports						
Oita Airport	Japan	1970-C	103	0.1	4	Reclam
Nagasaki Airport	Japan	1971-C	163	1.5	18	Reclam
Boston NewAirport	USA	1971-P	735	16	15	Reclam
Honolulu Airport	USA	1973-C	400	0.4	9	Reclam
Lake Erie Int'l Airport	USA	1973-P	0734	13	14	Reclam
Chicago Lake Airport	USA	1975-P	4450	9	17	Reclam
L.A. Offshore Airport	USA	1975-P	4047	8	23	Reclam
Takamatsu Airport	Japan	1978-P	141	1	20	Float
Kansai Int'l Airport	Japan	1988-C	1159	5	20	Reclam
San Diego Airport	USA	1989-P	800	6	600	Float
Recreation Use						
Nagoya Port Kinjyuou Futou	Japan	1963-C	141	1.4	5	Reclam
Tampa Harbor Project	USA	1967-C	240	3.5	5	Reclam
Yokohama Daikoku Futou	Japan	1971-C	321	0.5	12	Reclam
Hart Miller Island	USA	1976-C	40	1.2	5	Reclam
Karita Artificial Island	Japan	1981-C	153	3.5	8	Reclam
City & Residential Use						
Port Island - Kobe	Japan	1966-C	436	0.4	13	Reclam
Monaco Offshore Is.	France	1968-P	6	4.8	300	Float
Hawaii Floating City	USA	1970-P	45.4	5	1000	Float
Rokko Is.- Kobe	Japan	1971-C	583	0.2	14	Reclam
Kawasaki Higashi Oogishima	Japan	1972-C	434	0.7	10	Reclam
Okinawa Aqua-Polis	Japan	1974-C	1	0.3	50	Float
Man-made Is Complex	Japan	1985-P	3000	2	25	Reclam
Offshore Is Project	Japan	1985-P	3400	5	30	Reclam
City Complex Is	Japan	1985-P	5000	5	30	Reclam
Shimizu Artificial Is.	Japan	1986-P	230	0.5	10	Reclam
Oomura-Wan Manmade Is.	Japan	1988-P	1000	2.4	22	Reclam

Abbreviations: Island - Is.; Power- Pwr; and Station - Sta; Netherlands - NLD.

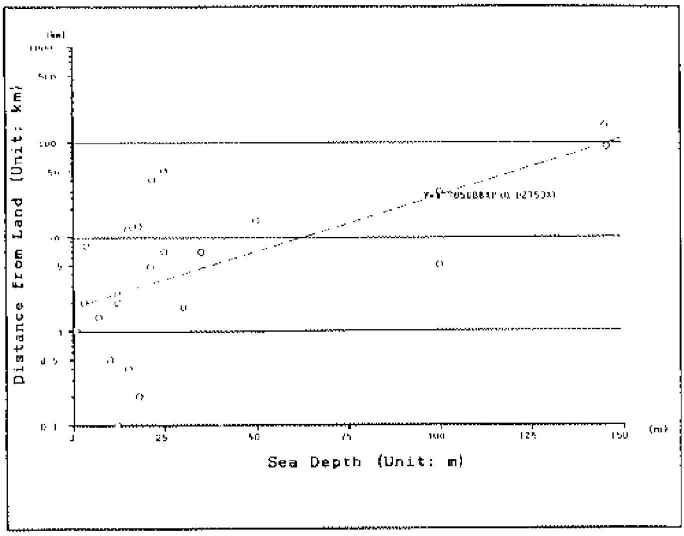

Figure 1. Production Project: The Relation Between Distance and Sea Depth

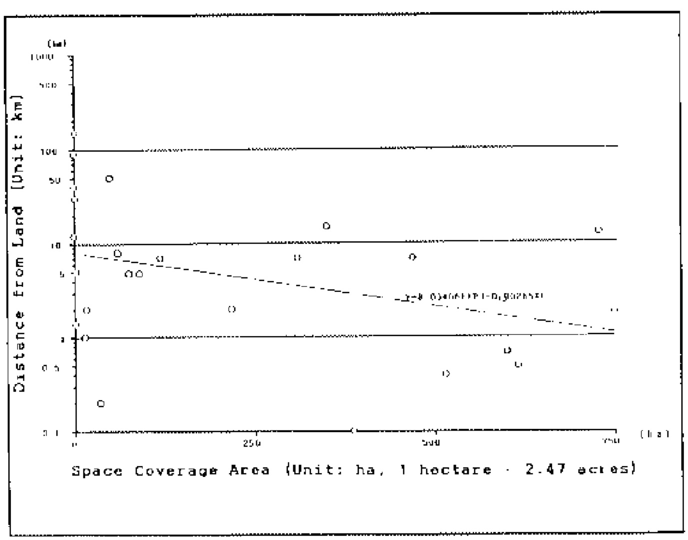

Figure 2. Production Project: The Relation Between Distance and Area

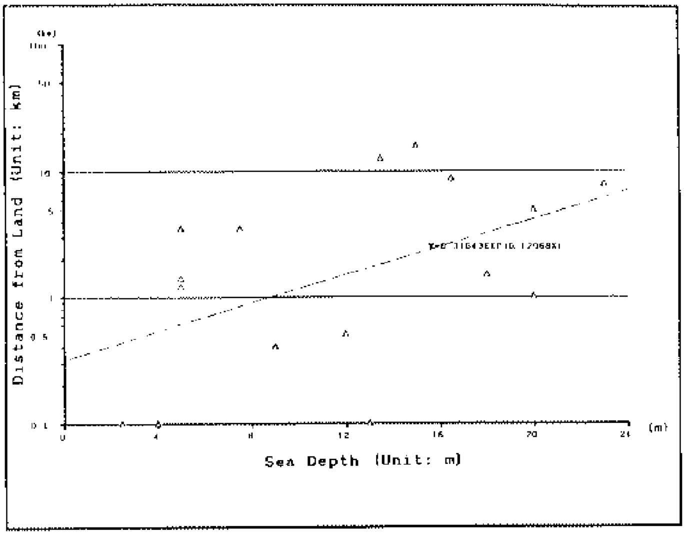

Figure 3. Urban Assistance Project: The Relation Between Distance and Sea Depth

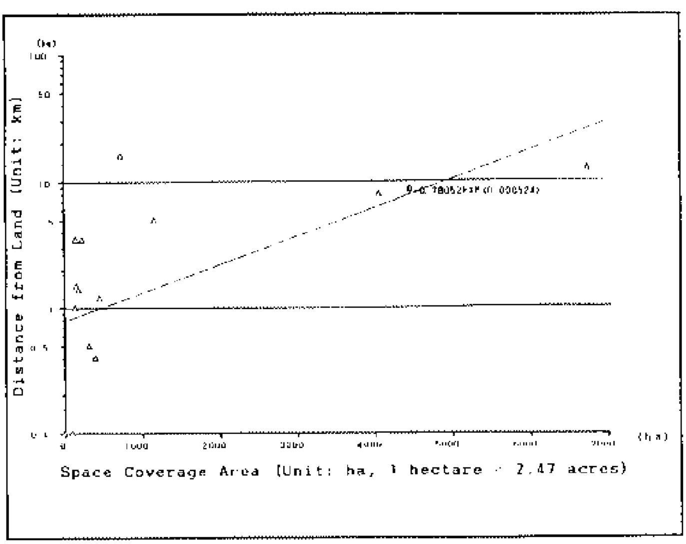

Figure 4. Urban Assistance Project: The Relation Between Distance and Area

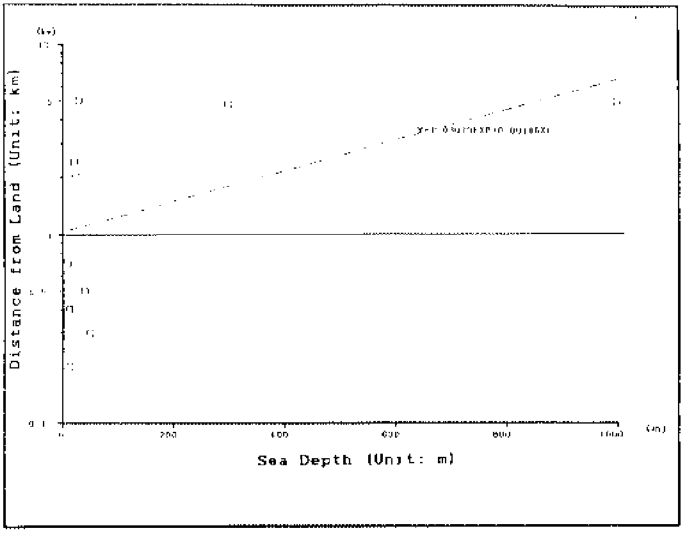

Figure 5. Marine City Project: The Relation Between Distance and Sea Depth

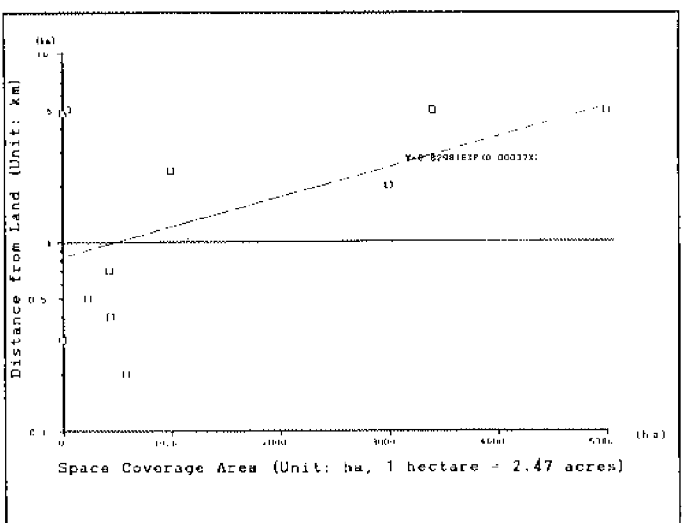

Figure 6. Marine City Project: The Relation Between Distance and Area

Structural Type

The reclaimed land type is the most common of both current and planned projects because of technical feasibility and relative economy. The floating-type structure is usually associated with deep sea, single-function small projects.

Relationship Between Sea Depth and Distance from Coast

There is an obvious growing trend for production facilities to be located in deeper waters because of diminishing coastal resources and access to more resources. In comparison, urban amenity assistance facilities are mainly located in shallow seas near large cities for such obvious reasons as access cost (which depends on distance and available modes of transportation). Urban residential facilities are either located in shallow, near-coastal areas (less than 20 m deep and 1 km distance from the coast) or in deeper offshore areas (20-100 m deep and about 5 km distance from the coast). The former is associated with reclaimed land-type structures while the latter is associated with either reclaimed land-type structures or floating-type structures.

Relationship Between Area Size and Distance from Coast

The size of production facilities tends to diminish with increased distance from the coast and these are mainly associated with single-function facilities. Conversely, the size increases with multi-functional features when the distance from the coast is less. Urban amenity assistance facilities tend to be very extensive, covering 100 to 10,000 hectares (ha) and are located near large cities. A tendency exists for these facilities to be associated with coastal, shallow sea, and large size development. Urban residential facilities increase in size with provisions for urban amenity assistance facilities, but their locations have become bipolarized to shallow sea, coastal development, and deep off-shore development.

Environmental Considerations

In the case of both urban amenity assistance facilities and urban residential facilities, public parks and gardens are planned as part of the utilization of artificially created land in order to harmonize between comfortable living conditions and to protect the natural environment and wildlife. Regarding ocean environment conservation, there is a trend to create artificial beaches instead of the conventional means of erecting barriers or groins to provide for beach conservation and protection.

Development Concept

Changes in the types of development projects reflect the requirements of the time period. Before the 1973 oil crisis, many ocean development projects were aimed at national visibility and growth, with companies competing with each other for the development of oil and gas resources. Since the oil crisis, however, projects associated with alternative energies such as solar and solar-derived energy became noticeable; the OTEC and wave energy conversion projects are examples. From the functional point of view, a single function plant construction has shifted to a multi-purpose use of reclaimed land. With regard to urban amenity assistance facilities, international airport projects on reclaimed land serving large nearby cities with close cooperation with international ports have become popular, due in part to the globalization of the economy. In the case of urban residential facilities, the conventional new-town-type projects have been increasingly replaced by multi-purpose projects, providing commercial functions with a large service industry sector creating and dealing with intellectual property rights, as well as conference functions for information exchange in addition to the residential function and its cultural and recreational amenities.

TRENDS AND FUTURE REQUIREMENTS

Trends

The changes in ocean space utilization reflect the changing economic and social needs. If the period from the mid-1960s to mid-1970s (to the mid-East oil crisis) is considered to be the first ocean development period, it was a period of resource exploration and development in both territorial waters and high seas. In this period, secondary marine industries emerged from the exploitation of oil, minerals, and fish resources. Most projects using ocean space were associated with heavy industries or the concept of coastal industrial cities which would process and exploit marine resources.

In contrast, the second ocean development period lasting from the mid-1970s to the mid-1980s can be regarded as an age of alternative energy development to respond to the oil crisis. This included an emphasis on nuclear power, and solar and solar-derived energy. An offshore nuclear power plant was designed for a site off the east coast of Florida. Examples of solar-derived energy include ocean thermal energy conversion (OTEC) and wave energy conversion projects. It was a period dominated by the problem-solving type ocean development concept which addressed not only the development of alternative energies, but also the creation of alternative space to deal with the overcrowding of cities and the preference for the amenities of coastal living. An ocean city project and a maritime airport project are the best examples of such projects. Efforts were made to solve problems on land using ocean space.

The third ocean development period commenced in the mid-1980s and continues today. It can be described as a period of integrated multiple-use of coastal ocean space influenced by the globalization of ocean development and the tendency towards tripolarizing the international economy. The dominant status of tertiary industries which account for more than 70 percent of the GNP have been pressing the secondary industry-based ocean development to transform to service-type industries and high value-added industries.

The vast consumption of fossil fuels since the industrial revolution, increasing urban development, and the gradual disappearance of the tropical rain forests may cause the global environment to become increasingly warmer. The conventional symptomatic treatment or problem-solving approach to ocean development is only partially capable of handling this new situation, requiring the urgent adoption of a preventive and target-setting type ocean development approach. At the same time, the infrastructures of such large cities as New York, London, and Paris (built at the beginning of the 20th Century) are showing signs of urban deterioration, and the construction of a new infrastructure suited to the new information-oriented society and global marketplace of the 21st Century is needed. The components of such a new infrastructure include international transportation complexes integrating sea, land, and air transportation and performing media functions; international exchange facilities such as convention centers for the exchange of people, goods, money, and information; and intelligent business centers. In addition, the research and development of large-scale environmental control technologies will contribute to the conservation of the global environment. Such an approach can be described as social capital enhancement-type ocean development.

Future Requirement

As described earlier, we are now in a period of integrated multiple-use of coastal ocean space as we approach the 21st Century. The outlook differs from the conventional singular approach of ocean development, with opportunities for bold new concepts.

The first ocean development period showed a distinct tendency towards offshore, deep-sea projects, mainly in search of seabed resources. The corresponding structures tended to be floating, single-function types in view of economy and mobility. The second ocean development period focused on alternative energies including extraction of ocean energy, and also as a period for construction of urban amenity assistance facilities to solve the various problems encountered by major port cities trying to combine production/distribution functions with basic urban functions. The third ocean development period focuses on the information-oriented global marketplace and integrated multiple use of ocean space by such megapolis blocks as the European Economic Community (EEC), North American Economic Community (NAEC), and the Asian Economic Community (AEC), leading to the consolidation of the international infrastructure for the 21st Century.

Construction of a new maritime infrastructure for transportation, information/

communications centers, urban utilities, and amenities is needed to revitalize international cities along the world's coasts. The expected population increase and the migration of the population to megapolis blocks will contribute to the greater consumption of resources, thus accelerating programs to probe and develop new marine resources of the EEZ and the deep ocean.

The next generation requirements for ocean development will first include the development of global environment (oceanic and atmospheric) control technologies using the various inherent capabilities of the ocean. One underlying concept put forth is "The Ocean will save the Earth." Secondly, clean energies and food resources will be developed. One leading candidate for this is a multi-purpose OTEC using the ocean's thermal energy for direct use and secondary conversion for hydrogen fuel production. A large-scale seafood production system using cold water nutrients derived from OTEC operation will have considerable potential. Also, artificial upwelling systems can be deployed in a large network to enhance fishery stocks. The development concept for such systems can be termed "Environment Friendly Ocean Development." Thirdly, the creation of a coastal city network for mutual benefit and interaction on a global scale will become an important theme, facilitating the introduction of a safe, rapid mass transportation system; and the construction of an integrated infrastructure. This is in accordance with the basic concept for a "Prosperous Symbiotic System for Ocean Space Utilization."

CONCLUSIONS

Coastal ocean space and associated development projects have evolved to a level in which technology is capable and available to address many of the present and future requirements to satisfy multiple-user needs in harmony with the environment. Environmental assets must be considered in our accounting system and perhaps economic forces could be used to preserve the environment. A healthy economy can only survive with a healthy ecology. Seaward extension of many major coastal cities or regions can be used to develop a new more integrated social, economic, and environmental infrastructure. This could include provisions for a centralized, more rapid multi-made transportation system integrating air, sea, and land transport of people and goods. It could also provide an integrated complex for comfortable living, recreation, and cultural activities, along with a co-located working environment mainly concerned with information-oriented and high-technology products.

Seaward extension could be a direct extension of the shoreline; an artificial island linked by bridges or tunnels; or an offshore floating facility or city which can be linked in the same way; and/or by a high-speed surface craft. As a floating city is located further offshore, other supportive and complimentary ocean facilities can be incorporated in future designs. These include ocean energy with by-products for freshwater, aquaculture, calm seas, and air cooling; artificial upwelling to enhance photosynthesis and fisheries production via open-ocean ranching and artificial habitats; production of hydrogen from electrolysis of seawater to provide clean fuel for power plants and transportation; environmentally compatible mineral extraction from seawater and the seabed; and a base for environmentally compatible ocean industry.

Coastal ocean space can be developed in an integrated multi-user/multi-function to satisfy social, economic, and environmental needs.

The concepts and ideas presented in this paper are the views offered by the authors and do not necessarily represent the views of any organizations with which they are affiliated.

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10

Panama — A New Set of Locks

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ABSTRACT

With world trade projected to rise significantly over the next 5 years, once again the adequacy of the Panama Canal to handle the increased traffic has been questioned. Currently, there is a trinational treaty organization charged with studying the feasibility of efforts to increase the commodity throughput across Panama.

The 76-year-old Panama Canal has experienced several improvements in order to facilitate the increasing demands of traffic. Although channel widening, lighting for night time traffic and several non-structural improvements have increased the Canal's capacity, they did not solve the size constraint imposed by the Canal. The locks restrict ship sizes to the order of about 65,000 deadweight tons. Therefore commodities such as crude oil, coal and now grain are being driven away as economies of scale justify the longer routes.

It is obvious that in order to meet future demands, either a new set of larger locks with an enlarged channel or a sea-level canal will be required. There are advantages and disadvantages to both. Environmental issues may be the deciding factor. The decision will be made as a result of an international cooperative effort.

INTRODUCTION

Currently the Panama Canal handles approximately 33 ships per day, but size is restricted to a maximum of about 65,000 deadweight tons (dwt). While this figure

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represents a little over 90 percent of the world's fleet, it only accounts for about half of the carrying capacity. Furthermore, the combination of traffic volume and ship size is approaching the transit capacity of the Canal. Ship size constraints and limited Canal transit capacity are responsible for generating the current feasibility study.

Although the choice of improvements to be studied is not restricted to any one mode of transportation, realistically, the choice of improvements is between expanding the dimensions of the Canal and concurrently adding a third set of locks or constructing a sea-level canal.

Either alternative must take into consideration not only the advantages and disadvantages of one over the other, but also competition from non-Panamanian routes such as the U.S. landbridge, as well as national competition provided by the trans-Panama oil pipeline. While it is clear that the Canal's capacity must be improved to meet the growing demands of world trade, the question remains as to what is the most feasible improvement to be made and what is the design of ship to be served.

Care and planning are crucial for deciding the best alternative. Environmental issues, possibly the deciding factor, are as mammoth as the alternatives. The needs of the host country have to be balanced with the needs of the users. That is why this is a trinational study.

EXISTING TRANS-PANAMA TRANSPORTATION SYSTEMS

Panama has two links between the Atlantic and the Pacific Oceans. The Panama Canal carries all commodities while the Panamanian pipeline is used only to transport crude oil.

The Panama Canal is a 80-kilometer long water link, connecting the Atlantic and Pacific Oceans. It consists of short sea-level sections at either end and a long elevated section between. The elevated section, Gatun Lake, is separated from the ocean approaches by twin sets of locks whose chambers are 305 meters long, 33.5 meters wide, and provide 12.5 meters of water over lock sills under normal conditions. The locks at the Atlantic end have three lifts between sea level and the surface of Gatun Lake, regulated between 24.9 and 26.5 meters above sea level. The Pacific end of the Canal has two sets of locks and dams: the Miraflores Locks, which raise vessels in two stages from sea level to Miraflores Lake at an elevation of 16.5 meters, and the Pedro Miguel Locks, which raise vessels in one lift from Miraflores Lake to Gatun Lake. All locks provide two parallel lanes which can accommodate traffic in either direction independently. The section through Gatun Lake is 38.6 kilometers long and has channel widths varying from 153 to 305 meters. The Gaillard Cut, located at the south end of Gatun Lake, is a 12.9 kilometer reach through the continental divide which has a channel bottom width of 153 meters.

Approximately 12,000 ships transit the Canal annually, carrying a total of about 150 million metric tons of freight. By volume, this represents about 5 percent of the world's deep-sea trade. Tolls for this traffic amount to about $330 million.[1]

The capacity of the Panama Canal is limited in two ways: the size of vessels and the number of transits which it can accommodate. The maximum ship size is restricted to ships whose length, beam and draft are less than 305, 33.5 and 12 meters, respectively. Although the Canal can service all but about 10 percent of the world's fleet, an ever-growing percentage of transits is by ships with increasingly greater widths

Channel width in both the ocean channel entrances and through the continental divide preclude unrestricted two-way traffic of Panamax size ships (ships whose widths are from 30.4 to 33.5 meters). The capacity for the present ship mix is estimated to be 39 vessels per day.[2]

Canal water time, defined by the Panama Canal Commission as the sum of queue and transit time, has increased annually since fiscal year (FY) 1983, from an average of 20.1 hours to 24.0 hours in FY 1987 to 24.4 hours in FY 1990. Canal transit time is a function of ship size. For example, a deeply laden Panamax ship requires 40 percent more time for lockage than a deeply laden 90- to 95-foot beam ship. The basic significance of larger, beamier, deeper draft ships transiting in greater number is the increased handling time. In addition, these ships are penalized for their size by having to wait to travel in alternating convoys during daylight hours only.

While the size creep in Panamax traffic is slow, it is steady. From 1983 to present the percentage of ships whose beams equalled or exceeded 30.4 meters has increased from 20 to 23 percent.[3]

The first competition to the Panama Canal occurred in the 1980s. The Panamanian pipeline has diverted all of the Alaska North Slope (ANS) crude oil from the Canal, and the United States landbridge has captured a significant quantity of all water route container traffic from the Canal. The growth in the landbridge has spawned the first "Post Panamax" containership (too wide for the Canal) which was constructed in 1988. These diversions of traffic have temporarily relieved the stress on the capacity of the Canal.

In some notable cases, such as coal exported from the Caribbean coast of Colombia, economies of scale on longer routes justify bypassing the Canal. Now that several U.S. ports are deepening their channels there may be further diversion of the bulk trades.

From a different point of view, the trans-Panama pipeline is a supplementary alternative to the Panama Canal, exclusively carrying Alaska North Slope crude oil across the Isthmus of Panama to refineries on the Gulf and East Coasts of the United States and U.S. Virgin Islands.

Opened in 1982, supertankers from Valdez, Alaska, offload crude oil to a terminal located on the Pacific Coast of Panama. The crude oil is then transported through a 131-kilometer long, 0.9-meter diameter pipeline to holding tanks on the Atlantic Coast of Panama. From these tanks it is delivered to ships about two kilometers offshore, via two catenary anchor-leg mooring bouys.

The Pacific docking facilities accept tankers of up to 265,000-dwt capacity; the capacity of the pipeline is 800,000 barrels per day and the Atlantic mooring buoys are designed to handle ships up to 139,000 dwt, although the natural depths are in excess of 18.3 meters.

Since its opening, the annual throughput of ANS crude oil through the pipeline facility has gradually dropped to about 25 percent of its carrying capacity due to a combination of increased consumption on the U.S. west coast and decreased production of ANS crude. The long range outlook is for a gradual decrease in ANS traffic to Panama unless major environmental objections are overriden with respect to untapped Alaskan and Californian oil reserves.[4]

ALTERNATIVES TO THE PANAMA CANAL

Over the years several proposals have been advanced for permitting larger ships to transit the Isthmus of Panama in order to increase the cargo capacity across Panama. This paper will address the differences between adding a third set of locks and constructing a new sea-level canal.

Improving the Existing Canal

There are several structural modifications which have been implemented over the years, improving the capacity of the Panama Canal. However, all the potential structural and non-structural modifications have been exhausted except for widening the Gaillard Cut. The only way to substantially increase the the capacity and service larger ships is to add a third set of locks and enlarge the channels.

Until the current feasibility study has sufficiently advanced, one can only make an educated guess at the appropriate chamber size for a third set of locks. As seen in Table 1, locks having the same length as the existing locks but with widths of 45.7 meters (to allow 1.5 meters of clearance on either side) and the appropriate depths, would accommodate 97 percent of the world's ships.[5]

Table 1

1989 World Fleet by Length and Beam

	Overall Length, meters		
Beam, meters	**30-304.9**	**305-318.**	**319-457.3**
6-32.2	23,465	7	0
32.3-36.6	402	1	0
36.7-42.6	794	0	0
42.7-91.5	360	58	352

There have been a number of proposals over the decades to add a third set of locks. Excavation was even initiated in 1939 but never completed. All proposals, except one, have been for a triple lift system. The lone exception was for a double lift system.

In the present study, consideration will be given to a single lift lock plan as well as a multi-lift system. By comparison to the triple lift locks, a single lift system would eliminate four of six chambers and associated appurtenances. Furthermore, a single lift chamber has a capacity advantage over a multi-lift system.

On the other hand, a single-lift system has certain potential drawbacks. First, the downstream gates would have to sustain a 26-meter head differential and provide a vertical seal spanning approximately 46 meters. Second, a chamber having a 26-meter lift would discharge more water per lockage than the triple lift system. Third, while the existing "mule system" could be used to guide and assist ships moving between the chamber and Gatun Lake, a new system will have to be developed to assist movement to and from the ocean approach channels. Finally, there is a higher probability for salinization of Gatun Lake.

There are various gate systems which would need to be evaluated to determine whether they could provide an adequate, that is, safe and feasible seal. Maintenance and replacement considerations would have to be incorporated in the design.

Water conservation would be achieved through storage basins and a pump-back system. Lock entry may be facilitated by either limiting ship size or providing a cable "come-along" system. Flushing or air screens would minimize the entry of salt water during entry from or exit to the ocean approach channels.

Gates

The ocean-side gates present the major structural design challenge in that they must resist a 26-meter head as well as span a 46-meter wide chamber. Below are three potential schemes.

1. Slide Gate System

Either straight or curved (arc) gate leaves could serve in place of traditional mitre gates. Rollers would sustain the weight and relieve the traditional rotational stresses produced by mitre gates and would eliminate the need for the double skin provided on the existing gates. However, to keep the wearing forces down, styrofoam or other bouyant products mounted on the gate would make the gate neutrally bouyant. The downstream sill would produce an adequate bottom seal.

However, slide gates would have certain problems. One is the weight of a 46-meter high and 27-meter wide gate leaf. Unless made of lightweight alloys the weight of such a gate would make replacement time consuming and difficult. A second is that a slide gate has a greater propensity for opening and closing problems resulting from the potential for trash to collect in the slide track than the traditional mitre gate system. To eliminate this problem, the gate could be hung from a horizontal track above the chamber. Trusses would allow for extra air draft.

2. Combination of Slide Gates and Lift Gates

Perhaps a split system comprising a combination of counterbalance lift gates and slide gates could serve as the ocean-side or downstream gates. Slide gates would extend from the bottom of the chamber to an elevation just above extreme high tide level. Likewise, a lift gate structure would extend from the slide gates to slightly above Gatun Lake level.

The lift gate would have to adequately mesh with the lower slide gates. In the open position the gate bottom would have to be raised to an elevation to provide the necessary air-draft for ships entering from or existing to the ocean approach channels.

From a maintenance standpoint, this system offers some advantages. The slide gate recesses would offer an easy access opportunity for maintenance. The recessed chamber could be dewatered and used to inspect and either repair or replace the side gates as appropriate. A scaffolding arrangement could facilitate easy inspection and routine maintenance for the lift gates.

3. Sector Gates

Sector gates could also serve as downstream gates. With the pivot point within the line of the guide walls, stop logs could be used to close the recess opening for maintenance. However, such an opening during normal operation, produces a discontinuity along the guide walls which would pose a safety problem to the ships.

Ship Entrance and Exit Guidance and Assistance Systems

The existing mule system would serve ship movements between the chambers and Gatun Lake. Due to the proposed 26-meter lift, the mule system is not adaptable for the lower chamber level ship movements. A new system would have to be developed to guide and stabilize ships during ingress and egress between the chambers and ocean approaches.

1. Horizontal Mooring Bit

A recessed or stepped horizontal track could be used, somewhat similar to a floating mooring bit, for ships entering from the ocean. The difficulty arises in a) connecting and b) maintaining a reasonable tension as the ship and carriage move into the chamber.

2. Flushing Assisted Exiting

Exiting the chambers, in order to enter the ocean approaches, could be facilitated by "flushing." This would require a second conduit system in order to introduce lake water into the lake-side end of the chamber to produce a head or gradient to help flush or push the vessel out of the chamber.

3. Exiting Alignment Problem

Without the mules there would not be a mechanism to control ship alignment while exiting. Perhaps a simulation model could be used to determine whether "bank suction" would tend to pull the ship to one wall or the other.

Water Conservation

There are both structural and non-structural approaches to conserve water. A single lift system would require on the order of 436,000 cubic meters of water for each chamber filling compared to the 205,000 cubic meters required in the exiting thriple lift system. The elimination of mitre gates conserves around 15 meters in chamber length required for the arc of their swing.

1. Non-Structural Measure

A non-structural method for reducing lockage water requirements is to employ alternate direction lockage. This would be roughly half of the water needed for convoy movements.

2. Structural Measures

Storage basins on one or both sides of the lock chamber could be employed to recycle water used during lockage. This (these) basin(s) would receive water each time the lock chamber is lowered. This water could then be pumped back into Gatun Lake or part of it could be used for refilling the chamber directly.

Recycling basins might require a more complex lock emptying system than conventional systems. Unless the pumping were concurrent and at an equal rate of discharge compared to the lock chamber emptying only a percentage of lockage water would be recyclable.

Salt Water Barrier

The locks and dams provide a salt water barrier between the ocean approach channels and Gatun Lake. However, as with the existing chambers, each lockage has a potential for introducing salt water into Gatun Lake.

With each opening of the downstream gates, salt water enters the lock by pressure differentials and by displacement of the exiting ship. The latter, of course, has the greatest impact.

Air curtains would counter pressure differentials and flushing would reduce the potential of salt water displacement.

Other Considerations

With the more modern filling and emptying culvert designs, ship movement in the chamber should be minimal but would have to be investigated to determine the need for fendering of the ship as it is raised or lowered. Also, the huge volume of water required to fill the lock chamber, depending on the rate of discharge, could result in seiching in Gaillard Cut. The geotechnical stability of the formation along Gaillard Cut is another concern. Studies indicate that Gold Hill and other features along Gaillard Cut are active slides. Indiscrete widening could actually hasten the slide process.

As can be seen from the above discussion, there are a number of engineering challenges for a single lift system. Assuming that they are resolvable, a single lift system would have to be compared to a double and triple lift system in terms of cost and risk. If the single lift system is the most costly, then it should be discarded from consideration. However, if it is the least expensive, then risk has to be assessed.

All of the above mentioned problems for a single lift system are minimized by the implementation of a double lift system, but to what degree remains to be assessed. For each additional lift, there is a loss in capacity.

Construction of a Sea-Level Canal

There are two plausible routes for a sea-level canal in Panama: the existing Canal location (referred to as Route 14) and an area about 11 kilometers to the west and parallel to the Canal (referred to as Route 10).

The design channel for a sea level canal should be based upon the same design ship as chosen for a lock canal with variations for sensitivity analysis. Previous studies examined the feasibility of a Route 10 sea-level canal. The U.S. Army Corps of Engineers released a comprehensive study in 1970 evaluating several routes and types of canals, with respect to Route 10, they designed a gated-canal in order to reduce tidal velocities to an acceptable level.[6] The subsequent Vergara[7] and Nagano[8] reports assumed that massive artificial embayments achieved by several-mile long breakwaters would resolve this problem.

Like the single lift lock concept, a sea-level canal also provides some engineering challenges. The major challenge is the navigability of a sea-level canal. The mean tidal range is 3.9 meters on the Pacific and 0.2 meters on the Atlantic side. Thus during the diurnal tidal cycle, there would be a mean difference of about 1.8 meters. Tidal gradients could produce unmanageable navigation velocities for periods during each tidal cycle. Spring and extreme tides exacerbate this problem.

Tidal velocities would also have to be taken into account with respect to the design and cost of bank protection necessary to prevent caving and subsequent channel degradation.

The intersection of the various rivers would require diversion or energy dissipation structures to prevent tremendous erosion of watersheds due to an artificially induced gradient at the "new mouths" of these rivers where they would intersect with the sea-level canal.

Since the release of the Corps' 1970 report addressing an interoceanic sea-level canal across Panama there has been a strong environmental concern. The Corps' effort, by today's standards, was deficient in conducting an adequate biological inventory and hydrographic surveys in the potentially affected areas to allow a proper assessment of the consequences of connecting the oceans. It has long been recognized that a complete biological base line survey is the preliminary step in evaluating the ecological requirements of species in their present, normal environment. Without this one cannot extrapolate the consequences of the transfer of species between oceans.

One of the environmental contractors for the 1970 Corps Study estimated that 10,000 species lived along Panama's two coast lines and of that number only 1,000 were thought to be common to each.

It is unfortunate that such long standing concerns have not been investigated by either the Smithsonian or the Panama Canal Commission, but they have not been funded to perform such studies. Unfortunately both the time and the resources to conduct a proper baseline survey are beyond those available to the present feasibility study. However, work performed during the intervening years will go a long way to help differentiate the qualitative environmental impacts between adding a third set of locks and constructing a sea-level canal. In addition, Panama has been blessed with very active participation by the Smithsonian Tropical Research Institute since the 1920s, and its environment is thus well documented by comparison to other countries of the world. A free flowing interoceanic connection could result in a significant ecological hazard by the introduction of unknown parasites and pathogens. Two known predators from the Pacific are the Yellow-bellied Sea Snake and the Crown of Thorns Starfish.

Socio-economic considerations

Since Spanish colonization, Panama has provided the major interoceanic link for trade across the Americas. The Republic of Panama, in many ways, is the product of the Panama Canal.

The service industry necessary to support the Canal and its military protection has been expanded to facilitate trade. The population centers of the Republic attest to the importance of the Canal. A canal that cannot meet future needs of world trade will have a negative impact on the country's GNP. Operation and maintenance of the post-2000 Canal, including whatever alternative is suggested and implemented, will have the single most important impact on the nation's economy. An alternative that does not consider the work force of the local population becomes a non responsive alternative.

SUMMARY

A third set of locks could be built to increase both the ship size limitations imposed by the existing locks and the transit capacity. Lock width and depth are more critical than lock length. Larger locks require larger channels, and they would expend more water. However, a single lift system with chambers measuring around 46 meters by 305 meters, with about 18 meters of water over the sills would accommodate approximately 97 percent of the world fleet.

A sea-level canal would require less staff but would be far more expensive to construct. Worse yet are the unquantifiable environmental risks that it poses.

All of the above considerations are being investigated in the present study which is due to be completed in 1993.

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"ODAIBA" Sea Purification and City Resort Concept

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ABSTRACT

"ODAIBA" is located in the north end of the Tokyo Bay just in front of the metrotropolitan area. Six artificial islands with breakwaters were built in 1853, and two of them remain now. Among them, ODAIBA No. 3, with two old breakwaters, plays the role of sheltering a small trapeziform semi-enclosed sea area. ODAIBA are historic and unique offshore civil engineering structures which have been accommodating wild sea birds and small animals like lizards and snakes. Such a natural place is quite exceptional in Tokyo Bay, which is totally surrounded by industrialized port and harbor facilities. This semi-enclosed sea area had been used as a temporary floating area for wood logs, but is now designated by the Tokyo Metropolitan Office as a sea park for recreational sports like boardsailing, traditional boating and recreational fishing. However, the water is contaminated and the seabed cannot be seen, although the average depth is less than three meters. On the other hand, there will be a "Tokyo Frontier" in 1994, a big international exposition to celebrate its decades-long construction project in the Tokyo waterfront. Our paper proposes a new concept of resort which includes purification and restoration of the sea. Our concept will create clean and beautiful sea areas by purifying water and improving bottom quality with advanced technologies. This will provide opportunities to touch and play with sea life for those who live and work in the area and visit the exposition. ODAIBA purification and city resort concept will be able to demonstrate a solution for cleaning up sea areas adjacent to big cities and is a great idea for a seaside oasis in a highly industrialized metropolitan area.

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INTRODUCTION

There are many plans and projects for large scale resorts in Japan, in the mountains and also the seaside, and almost all of them are located in the rural countryside. But basic users of these resorts live and work in metropolitan areas and must travel far to reach these areas on weekends, which can be expensive. We have to pay attention to the fact that the potential demand for recreational opportunities must be satisfied within metropolitan areas, for easy access to nature and relaxation on weekdays. City Resort is such an idea.

ODAIBA: ONLY POTENTIAL SITE FOR A CITY RESORT IN TOKYO

ODAIBA is the name of the artificial islands built in 1853 in order to defend Edo, now Tokyo, from the American fleet commanded by General Perry, who asked to open the nation for trade. At that time, six islands were built with breakwaters with shallow slopes around them. Among six, two remain now and they have been providing living space for wild sea birds and small animals. There are no other natural green areas remaining in Tokyo Bay except in ODAIBA, while all other surrounding areas are occupied by highly industrialized harbor facilities. As shown in Figure 1, ODAIBA is located in the north end of Tokyo Bay and now this trapeziform area made by ODAIBA No. 3 and two old breakwaters are designated as a sea park by the Tokyo Metropolitan Office. As a matter of fact, young people are enjoying boardsailing in this area and it has become a popular mooring spot for enjoying classic old-fashioned harbor cruises.

The Tokyo Metropolitan Office has been working to construct a high-tech urban center in this Tokyo waterfront area, including the ODAIBA area. According to the plan, 60,000 people will live and 110,000 people will work in this newly built urban waterfront in the 21st century. This big waterfront development project is said to require more than 8,000 billion yen. Figure 2 illustrates this urban development plan and Figure 3 is an aerial photo of the area. It is easy to see how the ODAIBA sea area has high potential for the city resort concept because of its location and natural surroundings.

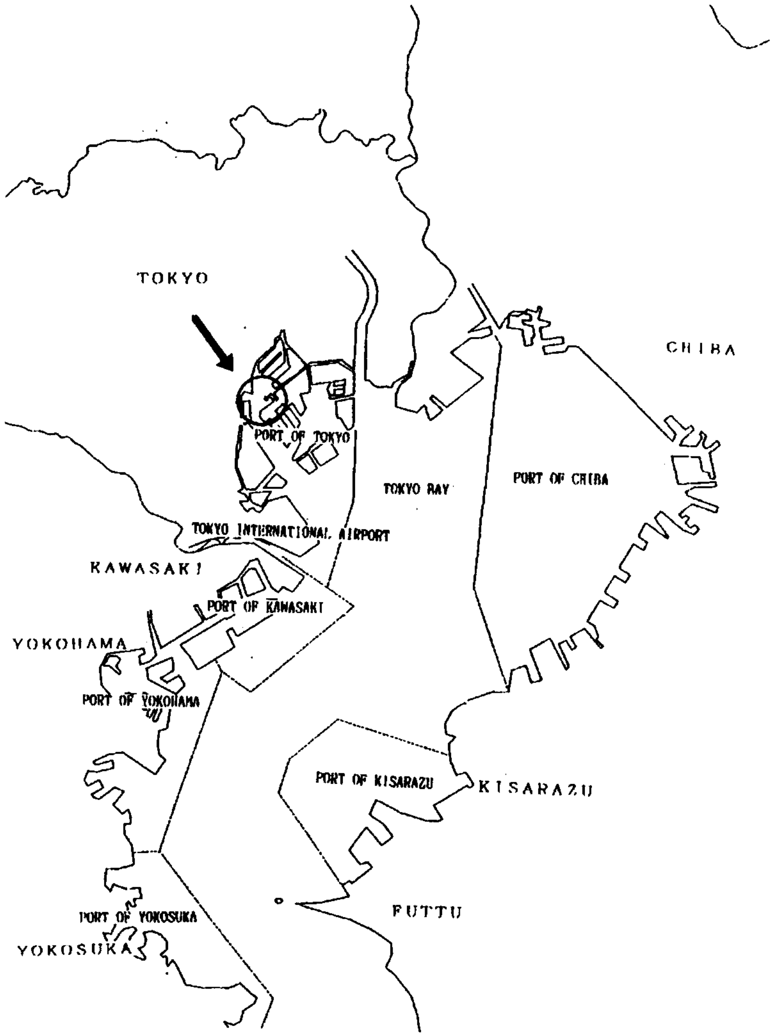

Figure 1. Location of "Odaiba" Sea Area

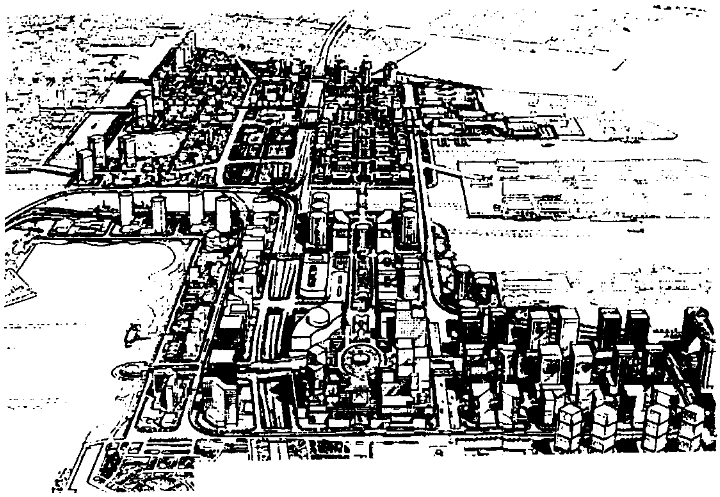

Figure 2. Image concept of Tokyo waterfront development

The Tokyo Metropolitan Office had also announced an international exposition, "Tokyo Frontier," in this area in 1994. The theme of that event is to exchange information and experience on the common problems with which the world's big cities are coping. However, there are very few plans to make use of the sea area in this big project. Now we propose to purify the water and improve seabottom quality and to create a clean and beautiful seaside oasis, the City Resort, in ODAIBA.

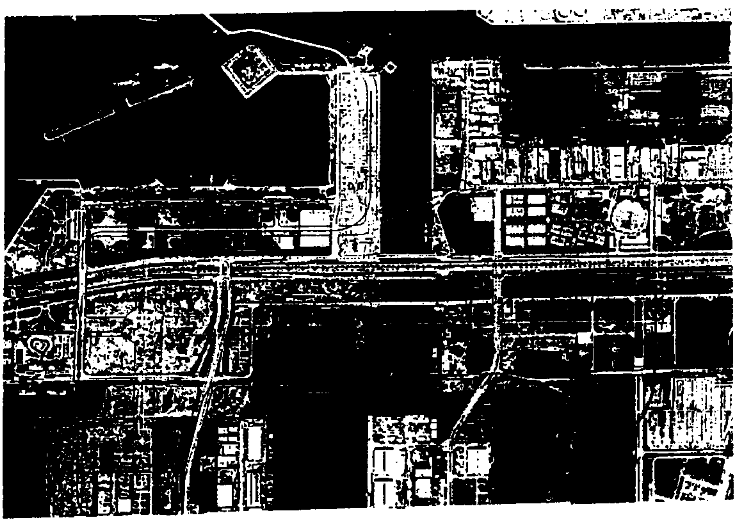

Figure 3. Aerial photo of the Tokyo waterfront development area

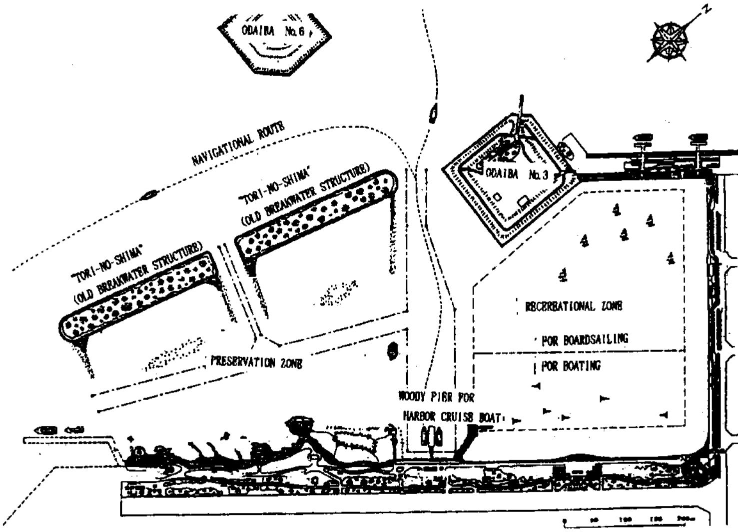

Figure 4. Present use of the ODAIBA Sea Park

PRESENT STATE OF THE AREA

As described above, the area around ODAIBA is a rather small trapeziform semi-enclosed area defined by ODAIBA No. 3 and two TORI-NO-SHIMA, old breakwaters made by rocks with shallow slopes. On the shoreline, a rocky tidepool subarea exists on the left-hand side, and the rest is sandy beach. The total sea area is divided into two sections; a preservation zone and a recreational zone which is actively used. Also, there is a wooden pier for a regular harbor cruise stop. Figure 4 provides a whole view of the area. Navigation routes in the sea area are strictly limited because of the shallow water depth. As shown in Figure 5, the average depth is between two and three meters, with four meters maximum depth. However, the seabottom is not visible, although it is no deeper than a normal living room.

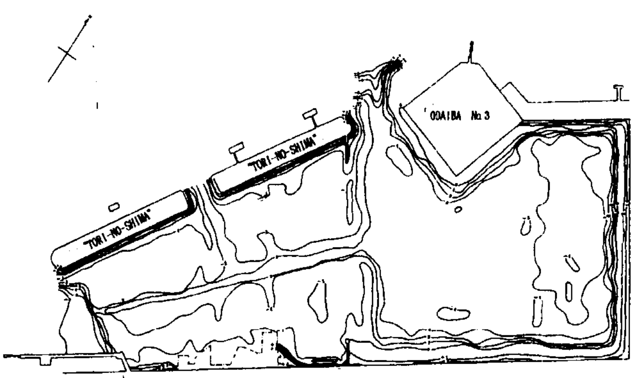

Figure 5. Seabottom topography of the ODAIBA sea area

This area used to be a pool for temporarily keeping wood logs. Because of this history, much wood debris has been found when it occasionally floats up from soft mud seabottom. Although the Tokyo Metropolitan Office has been working to clean up this sea area and it is slightly improved, the water quality and seabottom still remain less than good. In addition, tides and currents bring polluted water from Tokyo Bay into this small semi-enclosed sea area, so comprehensive measures to purify this sea area are needed.

HOW TO PURIFY THE SEA

The purifying methods we propose in this paper consist of a combination of mechanical filtering and enhancement of the self-cleaning capability of the sea itself. Excavation of trenches, dredging and sanding, the creation of tideland and seaweed grounds, which play a vital role in the self-cleaning capability of the sea, are the major means of cleaning, along with underground mechanical filtering facilities. Those ideas are shown in Figure 6.

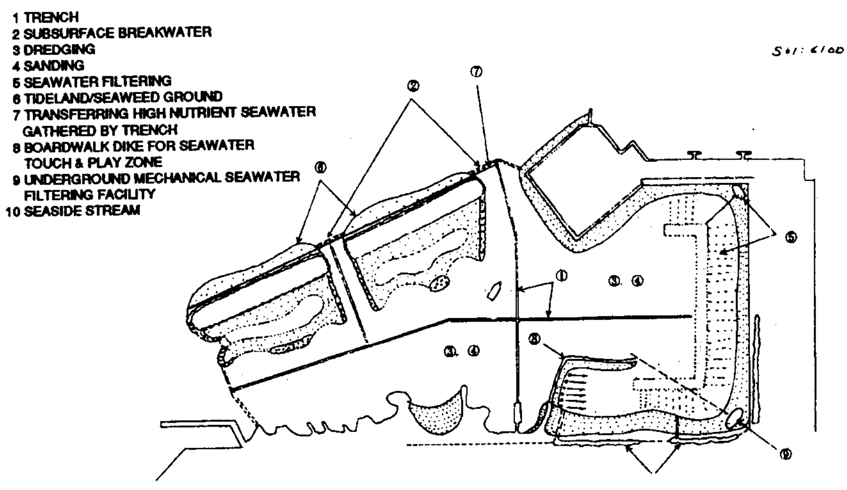

Figure 6. Deployment of sea purifying methods

One of the unique methods for purifying seawater is to use buried filtering pipes. Dozens of sets of filtration pipes will be installed, with water intake and outlet through the sand. The idea is that the sand layer itself is utilized as a filtering material. Combined with underground purifying facilities, cleaned seawater will be delivered to the sea area though the buried pipes, through the seaside stream for touch and play, and through the outlet to the L-shaped boardwalk dike area less influenced by the tide and current. With improved water quality, this zone will be a splendid play area for children and family. Trenches will gather the rather high nutrient water and very soft mud to be transferred to the tideland and seaweed ground for fertilization. These measures can make seawater transparent enough to see the shallow seabottom and also clean enough to be touched and played with. These purification methods are chosen because they will have little effect on the natural scenery. This concept is shown in Figure 7.

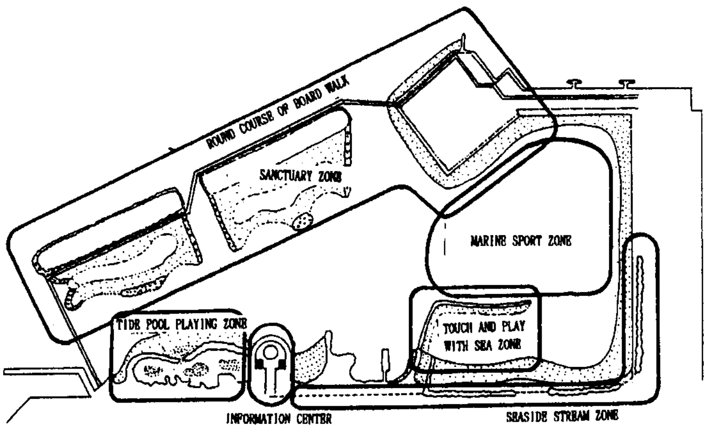

Figure 7. Zoning of Odaiba City Resort

ODAIBA CITY RESORT CONCEPT

The first stage result of this concept included the construction of a diving spot at the corner of the area as a symbol of purified seawater. This idea is also based upon the fundamental concept of small magnitude change of scenery by designing low buildings with sophisticated simple style and underground mechanical facilities. After five o'clock, quick access to scuba diving at a central part of the metroplitan area will be part of a wonderful resort system in the 21st century city. The bird's-eye-view of this concept is illustrated in Figure 8.

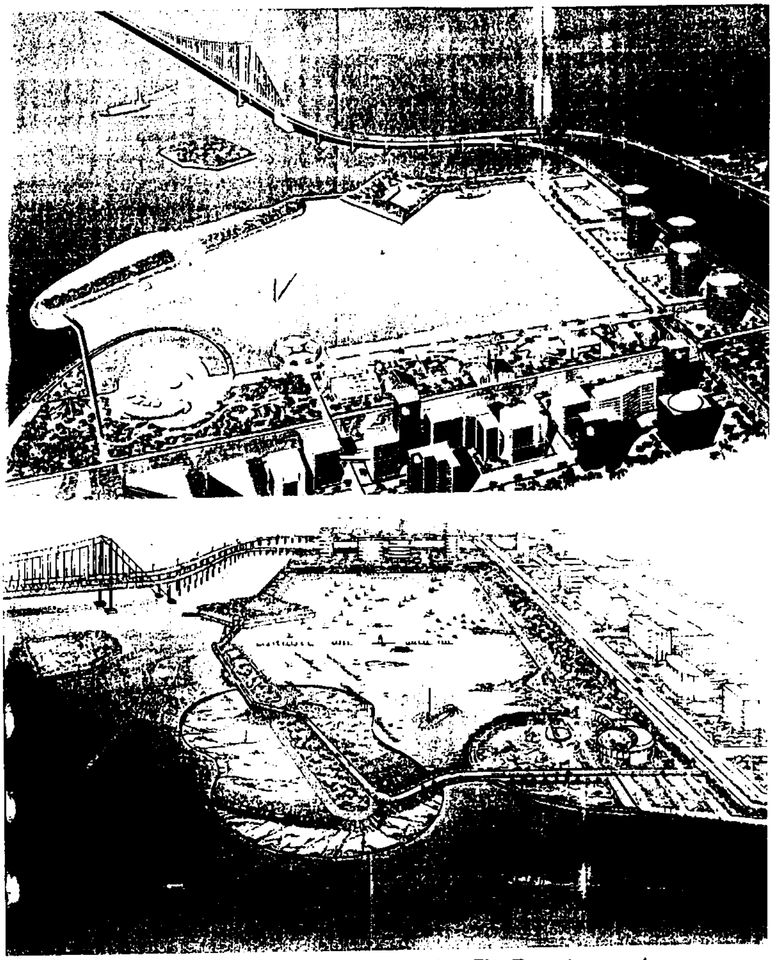

Figure 8. Birds' eye view of Odaiba City Resort concept

Although the ODAIBA area is designated as a sea park by the Tokyo local government, very little change in the natural scenery is allowed. Our second-stage study resulted in the concept described above. The only change of scenery is an L-shaped boardwalk dike, which will give people direct opportunities for touching and playing with purified seawater.

Of course, the round boardwalk along the ODAIBA island No. 3 and the two old breakwaters are another essential element of the City Resort. They enable people to enjoy various view areas both inside of the sea area and outside of Tokyo Bay. An Information Center will be installed as a part of the "Tokyo Frontier" event, and we propose that this center have a demonstration display of efforts to purify the seawater. It may even have a vertically designed structure with a small diving pool inside and an undersea walkway to and from the shoreside to allow people to see the purified seawater when they walk through. This underwater tunnel will allow people to watch the subsurface scenery at close range so they can appreciate its attractiveness. It also provides a venue for education about the clean-up efforts of the semi-enclosed sea in front of the big city.

CONCLUSION

ODAIBA sea purification and city resort concept is a symbolic idea of the challenge of purifying the sea and providing a real touchable and playable waterfront recreational oasis surrounded by highly industrialized urban development. A resort of this size, about 1 x 500 meter in sea area, will be realized with two to three billion yen for the initial design. We proudly propose this concept in order to upgrade the coastal environmental quality of the Tokyo waterfront development project.

If we do not make any effort for sea area restoration and purification in this ODAIBA area, we leave it as it is while advanced development continues on the land side of the shore. Why not have an artificially purified sea to create an oasis among high rise buildings? This is the ODAIBA Sea Purification and City Resort Concept.

ACKNOWLEDGMENTS

This paper is based upon the intensive study being made by the committee on the ODAIBA City Resort study organized in the Research Institute for Ocean Economics. Co-authors of this paper are the chairman, vice-chairman, coordinator of the committee and administrative staff of the Institute, respectively. We extend sincere thanks to the study effort on Tokyo Bay Restoration, about which we made a presentation at COSU I. This focused on the self-cleaning capability inherent in the sea itself. Again, we acknowledge all of the companies involved in this study and the advisors who gave us thoughtful insight whenever it was needed.

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Creation of New Offshore Space — Artificial Islands and Calmed-Water Areas

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ABSTRACT

Reclamation of coastal areas and construction of artificial islands have been carried out for many years in Japan. In recent times, projects for the construction of offshore artificial islands have also been planned and are being realized. Offshore artificial islands create calmed-water areas between such islands and the coast — areas that can meet a variety of social needs.

Through the 1980s the Kozai Club conducted investigations and research toward the realization of offshore artificial islands, under the guidance of the Ministry of Transport and with the cooperation of the Japan Federation of Economic Organizations. This paper describes briefly the history of the Kozai Club's activities in this field during a decade of work, the present situation of Japan's utilization of its coastal areas, and the object and significance of creating new offshore space by offshore development. Conceptions of coastal space utilization in the future, with recommended steps toward realizing these concepts by means of offshore artificial islands, are also presented.

INTRODUCTION

Japan, surrounded by the sea, is a country of steep, rugged mountains. It has a population of 120 million, yet habitable areas account for only 30% of the country's total land area. It is estimated that Japan's population will reach 140 million by the middle of the 21st century. Accordingly, a vast additional area will be required for

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supporting society and the economy, for securing working space and for realizing an affluent life for the people.

As for living space, about half of Japan's population is concentrated in cities, towns and villages in coastal areas. Therefore, we have to conclude that the development and utilization of coastal areas have already reached their limits. Under these circumstances, more efficient utilization of offshore space must be achieved if the living space needed for the future is to be secured.

From this viewpoint the concept of offshore artificial islands must become the basis for a large-scale national project to promote an affluent society through the creation of new national land by comprehensive use of offshore space. Therefore, the advancement and realization of such a project have great significance for Japan. It is also necessary to consider the utilization of calmed-water areas between offshore artificial islands and the coastline that will be created by construction of such islands. Multiple uses for these vast calmed-water areas are conceivable, such as space for ports and harbors, for fishery and for marine recreation. A chain of adjacent artificial islands would create larger calmed-water areas than that behind a single island, providing still greater possibilities of multipurpose utilization.

An important consideration in the construction of these offshore artificial islands is the selection of an appropriate distance between the coast and the islands from the standpoint of efficient utilization, fulfillment of social needs, and environmental conservation of existing coastal areas. A comprehensive examination should thus be made of ways to utilize the sea area in relation to the distance between the coast and the islands to be constructed in each case.

On the basis of the aims and considerations mentioned above, the Kozai Club conducted investigations and research throughout the 1980s in regard to offshore artificial islands, under the guidance of the Ministry of Transport. This paper introduces key points of the results of that decade of work, followed by summary of a paper presented at the First International Symposium on Coastal Ocean Space Utilization (COSU I), held in New York in 1989. At COSU I, existing artificial islands and feasible concepts for future islands in terms of technology and social conditions were discussed under the theme of "Promotion of Artificial Island Construction in Japan." In the present paper, the object and significance of offshore space is introduced under the theme of "Creation of New Offshore Space." The concepts and future aspects of offshore artificial islands and concepts of how to use the calmed-water areas to be created behind wave-control structures (breakwaters) are also introduced here.

OUTLINE OF THE KOZAI CLUB'S ACTIVITIES

The Kozai Club is a trade association with 117 member companies, including 33 leading steelmakers and 84 representative trading companies that distribute iron and steel products. The Kozai Club undertakes a variety of activities for the orderly working of demand and supply of iron and steel products. They include investigation and research; preparation of statistical data; collection of information;

and data service regarding demand and supply of iron and steel products and their distribution. The Kozai Club also promotes the development of steel markets in the fields of construction, civil engineering, and offshore development, as well as the efficient utilization of steel products.

The research project on offshore artificial islands was commissioned to the Japan Federation of Economic Organizations by the Ministry of Transport. The practical research has been carried out by the Kozai Club's Offshore Development Promotion Committee, the members of which are some 150 persons in universities, the steel, shipbuilding and construction industries, and trading companies. The results of their activities have been published each year since 1980 under the theme of "Creation of New National Land." Table 1 summarizes the results of research on offshore artificial islands.

Table 1

Results of Research on Offshore Artificial Islands

Year	Research results
1980 1981 1982	● Technical tasks made clear for the feasibility study and construction of offshore artificial islands, on the assumption of location of coal-fired power plants on sea areas of water depth of up to 50 m, facing the open sea
1983	● Case studies of offshore artificial islands (1): Examination of utilization possibility of various artificial islands constructed in sea areas having different natural conditions such as Akita Bay, Shimizu Port, Shimonoseki-Kitaura and Omura Bay
1984	● Case studies of offshore artificial islands (2): Off Muroran, Miura Peninsula ○ Utilization methods for calmed-water areas
1985	● Devising of guidelines for the offshore artificial island plan ● Fundamental examination to undertake practical construction of offshore artificial islands ○ Examination of locations suitable for developing schemes for calmed-water areas
1986	● Survey of practical construction of offshore artificial islands (1): Surveys of examples and approaches ○ Comprehensive examination to evaluate the environmental effects of calmed-water areas
1987	● Survey of practical construction of offshore artificial islands (2): Detailed examination for business undertaking systems and examination of diverse developments of offshore artificial islands, which will be a long-term construction project ○ Case studies of the utilization of calmed-water areas (1): Examination of utilization possibility in sea areas having different natural conditions, such as Sea of Kashima, Niigata, Fukiagehama Coast and Kuju-kuri Coast
1988	● Survey of practical construction of offshore artificial islands (3):Surveys of various procedures required in various steps from planning to management ○ Case studies for the utilization of calmed-water areas (2):Sea areas such as Rumoi, Motobu and Old Yoshino River
1989	● Survey of practical construction of offshore artificial islands (4): Preparation of manuals for procedures and consideration points from planning to management, and propositions on cost-reduction measures for construction ○ Methods for evaluation of calmed-water areas and examination of utilization systems

Notes: ● Offshore artificial islands ○ Calmed-water areas

Research on offshore artificial islands

From 1980 to 1982, against the background of the second oil crisis, a study of the feasibility and technological problems of coal-fired power stations was conducted on the assumption that these stations would be constructed on offshore sites, shallower than 50 meters in water depth and facing the open sea. In 1983 and 1984, six case studies of the feasibility of utilizing multipurpose offshore artificial islands in sea areas having various natural conditions were made. (These concepts were reported at COSU I.)

From 1985 to 1989, research on the commercialization of offshore artificial islands was undertaken. Basic survey items, case study topics, procedures, measures to reduce cost, and other points for consideration were clarified. In 1987 and 1988, a number of concepts of future directions were drafted by examining the diversifying development of offshore artificial islands — a long-term project that will be described later.

Examination of efficient utilization of calmed-water areas

From 1984 to 1986, measures for utilizing calmed-water areas, selection of suitable areas, and an overall evaluation of the environment were examined. In 1987 and 1988, seven case studies of the feasibility of utilizing calmed-water areas in sea areas having various natural conditions were carried out. (They will be described later.) In 1989, a method for obtaining data to be used in examining efficient utilization of calmed-water areas and a method for unified evaluation of the size of calmed-water areas were worked out.

COASTAL AREA UTILIZATION AND OFFSHORE DEVELOPMENT

Utilization of Coastal Areas

Table 2 shows the current status of coastal area utilization.[1] About half of Japan's people live in cities, towns and villages in coastal areas facing the sea. These areas account for over 60% of sales in total national trade, and over 50% of industrial shipments, showing the great importance of coastal areas as a driving force in Japan's economy and society.

Table 2

Utilization of Coastal Areas

Items \ Areas	Unit	National total	Total of coastal areas	Closed bay or inland sea		Coastal areas facing the open sea		Reference
Length of coastline (incl. islands)	km	—	32,753	10,383	31.7%	22,370	68.3%	1983
Population	1,000	119,316	56,367	33,070	58.7	23,297	41.3	1984
Commercial sales	billion yen	501,193	302,397	231,808	76.7	70,589	23.3	1982
Industrial shipments	billion yen	235,527	123,504	87,036	70.5	36,468	29.5	1983

Note: % — In case of coastal areas as 100

Among coastal areas, those facing a closed bay or an inland sea are utilized in multipurpose ways. Such areas occupy only about 30% of Japan's total coastal length, but are inhabited by some 60% of the total population of coastal areas. They represent more than 70% of sales in trade and 70% of industrial shipments among all coastal areas, due to the accumulation of secondary and tertiary industries in these areas. In coastal areas facing the open sea, by contrast, only marine-products industries or sightseeing potential of the natural scenery are conspicuous. These areas still show a low level of utilization.

Table 3 shows the present situation of utilization of coastal areas in terms of ratio of areas facing a closed bay or an inland sea to those facing the open sea respectively.[2] The table indicates that the coastal areas facing the open sea have a total coastline length 2.2 time that of areas facing a closed bay or an inland sea. Yet the latter areas have 1.4 times the population of the former. Therefore, coastal areas facing the open sea have high development potential.

Table 3

Utilization of Coastal Areas

Items \ Areas	I	II
Population	1.4	
Population density	4.2	
Population of secondary industry	1.9	1.0
Population of tertiary industry	1.6	
Numbers of cities and towns (200,000 or more in population)	1.4	
Population of primary industry		1.6
Number of fishery organizations	1.0	1.8
Fishery values		3.6
Number of fishery ports		2.6
Number of fishermen for sport	1.0	1.0
Number of ports	1.0	1.0

Items \ Areas	I	II
Commercial sales values	3.3	
Industrial shipment amounts	2.4	
Number of enterprises	1.7	1.0
Delivery amount of fishery products	2.6	
Handling volumes of port/harbor cargos	3.3	
Coastal lines		2.2
National and seminational parks	1.0	2.8
Aquaria		2.0
Swimming beaches		2.5
Number of marinas	1.0	1.0

Notes: I — Coastal areas facing closed bay and inland sea
II — Costal areas facing the open sea

Existing artificial islands

Figure 1 shows examples of artificial islands built in Japan within the last two decades or now under construction at sites more than 200 m offshore. The figures also indicates distance from the coast, water depth, and size of each. Among these artificial islands, a great many are roughly in the range of 500 m offshore. None is sited between 1.5 km and 3.5 km offshore. Only one example each is found of an island at 3.5 km, 4 km or 5 km distance from the coast. The largest artificial island at a distance of more than 200 km from the shore is 615 ha in area.

The maximum water depth at the site is 24 m. Most of these islands are constructed at a water depth of 10 to 20 m. In addition, most are constructed in a closed bay or an inland sea, where there are concentrations of economic activity. Only two artificial islands have been constructed in the open sea around Japan — the Gobo Power Station and the Shibushi Oil Reserve Base. The stage has not yet been reached where multipurpose offshore space utilization combining offshore artificial islands in the open sea with calmed-water areas created in their vicinity has been realized.

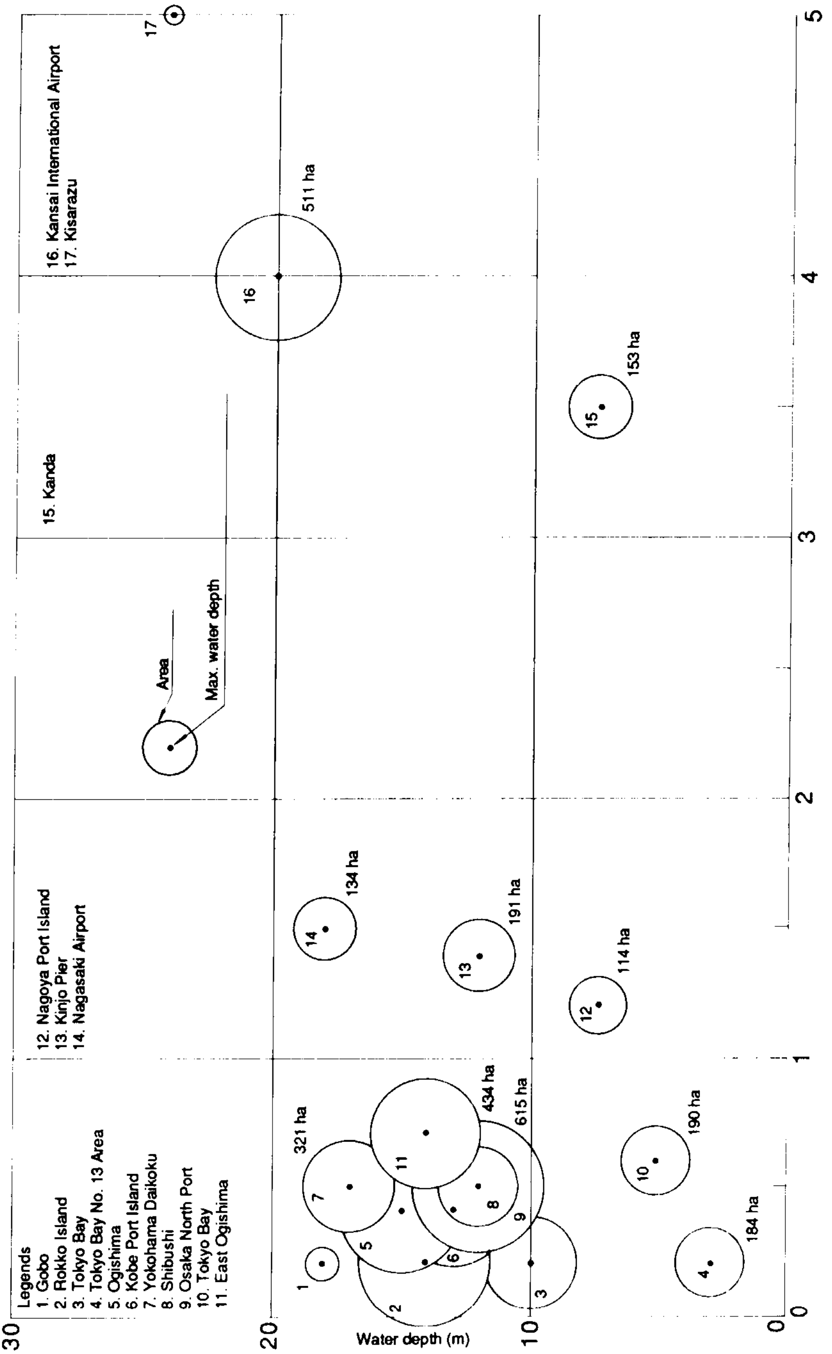


Figure 1. Typical artificial islands in Japan

Offshore development

Patterns for the development of offshore space utilization are classified into the following three stages, as shown in Figure 2:

(1) Reclamation of coastal areas: Reclamation centering on coastal areas facing a closed bay or an inland sea.

(2) Coastal artificial islands: Artificial islands that have a close relationship with existing cities and coastal industrial zones.

(3) Offshore artificial islands: Artificial islands used, along with the surrounding sea area, for multiple purposes.

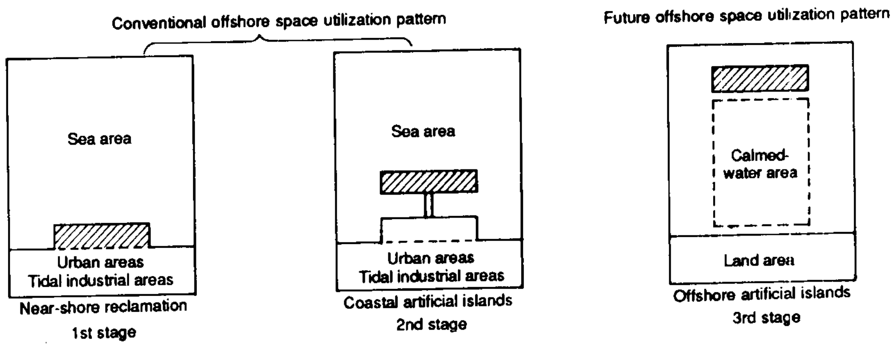


Figure 2. Combination of offshore space utilization patterns and offshore artificial islands

The first stage of offshore space utilization is the reclamation of coastal areas. Its purpose is to utilize new land created by drainage or reclamation of calmed shallow sea areas, centering on bays, the inland sea, and other protected water areas. Such new land has been developed as sites for industrial, urban or agricultural use. Recently it has been utilized more than ever to meet the growing demand for sites of urban redevelopment projects and housing.

The second stage is an approach that secures the existing shoreline and offshore space. It aims to preserve the existing beach environment, and at the same time to secure water areas between the existing shoreline and an artificial island as port space (sea route, anchorage, channel). It can be said that this method creates a coastal artificial island system, including new land areas and coastal areas, or offshore space. Recently it has become the leading approach to offshore space utilization, integrating in multiple ways the functions of port, city, recreation area and marine-products industry site.

The third stage, developed from the first and second approaches mentioned above, is the creation of new functional space — calmed-water areas — between artificial islands and coastal areas by constructing such islands at some distance offshore. It is the stage of multipurpose utilization of offshore space due to the farther-offshore siting of an artificial islands system, which ensure maximum utilization of the characteristics of both the artificial islands and the surrounding sea area.

The significance and object of offshore artificial islands and the role of calmed-water areas created behind these islands are described in detail below.

CREATION OF NEW OFFSHORE SPACE

Object of artificial islands

(1) Concept of building national land — Creation of new land

The construction of offshore artificial island has two benefits: it offers no hindrance to the utilization of existing shorelines or shallow water areas, and it creates valuable calmed-water areas between the coast and the offshore islands. This is a concept of creating new land on an entirely new premise. Offshore artificial islands and the calmed-water areas created behind them promise to meet the growing demand for space as the society develops and the economy expands toward the 21st century, by creating new offshore space. By expanding the national frontier, offshore artificial islands and the calmed-water areas that result will enhance the people's vitality and support progress toward an affluent life for people.

(2) Efficient, comprehensive utilization of offshore space

Japan, not a large country in land area, has a large proportion of rugged, uninhabitable mountain areas. Since ancient times, therefore, efforts have been made to expand the flatlands. This has been done by reclamation (the first stage cited in the previous section) and coastal artificial islands (the second stage). To reap the full value of offshore space, offshore artificial islands (the third stage) will now draw more attention. With such artificial islands as the focus, vast new usable space will be created, including the land area of the offshore artificial islands, calmed-water areas behind them, and existing land areas nearby.

(3) Promotion of offshore development

Japan profits greatly from the sea, from the interchange of goods and culture through maritime transport and from marine life as a source of food. In short, Japan has an inseparable relationship with the sea. By use of offshore artificial islands as a base, promising ocean development projects become feasible.

(4) Contribution to the development of science and technology

To construct offshore artificial islands under the harsh conditions of the open sea, highly advanced technologies from many fields must be applied. For every stage of investigation, planning and construction, goals for technological development can be determined. Achieving these goals thereby advances technology. There is no doubt that the construction of offshore artificial islands will generate new science and innovative technology.

(5) Contribution to international society

In addition to their social and urban functions, offshore artificial islands will have an extra dimension of internationalization — exchanges of information and trade that will serve the development of an international economy. By placing such islands at the center of its international exchange network, Japan can contribute much to global society.

(6) Vitalization of society and economy

Construction of offshore artificial islands will have an impact not only on construction-related industries but also on many others, including steelmaking, chemicals, electrical appliances, machinery and high-technology industries. The intertwining activities of society, commerce and industry on these islands and in the surrounding sea areas will have a broad-ranging economic impact on the country, and will contribute greatly to the vitalization of Japan's society and its economy.

(7) Influence on local communities

The business of enterprises operating on offshore artificial island and in the surrounding sea areas, the rise in local income due to growth of employment, and commercial activities in such areas will increase local tax revenues. In turn, sound financing can be secured and stabilization of the local economy can be expected. In addition, the construction of such islands will lead to further development of public facilities such as roads and ports in local areas and the districts surrounding them. In these ways the potential for development of local areas will increase.

The Role of Calmed-water Areas

The calmed-water areas created between the coastline and offshore artificial islands or wave-control structures such as breakwaters offer high potential for effective and flexible utilization. Examples of how calmed-water areas can be used for a number of purposes at the same time are discussed below.

(1) Recreation

Time available for recreation is increasing both quantitatively and qualitatively in Japan, due to the general increase in leisure time in recent years. The popularity of marine recreation in particular has grown year by year. Therefore, the need to develop sites for marine recreation in calmed-water areas is pressing.

(2) Industry

A shift to coastal fishery from the traditional emphasis on deep-sea fishery is being examined by many. Today, fish cultivation has become an important means of securing fishery resources along the coast. Calmed-water areas are regarded as promising sites for fish cultivation or reproduction. Multipurpose use of calmed-water areas can be achieved by installing power-generating units operated by wave power at the revetments of offshore artificial islands or on breakwaters. And for Japan, which is heavily dependent on imports for major natural resources, storage bases for these imported resources can be a promising utilization for a calmed-water area.

(3) Traffic and transport

For mutual connections among offshore islands, their calmed-water areas and adjacent onshore areas, traffic and transport must be closely considered in relation to all the facilities to be constructed in such areas. It is important to provide appropriate facilities for traffic access, not only within a specified area but also between that area and the surrounding district or between the specified area and like areas elsewhere. For example, calmed-water areas can be provided with facilities for anchorage of refuge, marine traffic and air traffic.

(4) Life-related facilities

The calmed-water areas behind offshore artificial islands have few obstacles, moderate wave conditions, and an atmosphere of freedom. These areas are well suited for such facilities as a marine medical treatment center, communications, or floating structures, according to the specific characteristics of each area. In addition, waste-incineration or sewage treatment facilities may be acceptable, depending upon the isolation of the calmed-water area involved.

CONCEPTS OF THE FUTURE

Concepts for future offshore artificial islands

Table 4 shows the concepts of six future offshore artificial islands. Each is a feasible plan in terms of technology and social conditions. As an example, the concept of International Distribution Center is shown in Figure 3. Table 5 shows concepts of four other offshore artificial islands. These are plans that require new technology and adjustments in social conditions for their realization. As an example, Figure 4 shows the concept of a Back-up City Land to serve as an area of refuge for people displaced by natural catastrophes such as a major earthquake.

Concepts of utilizing calmed-water areas

The calmed-water utilization concept discussed here is based upon the installation of wave-control structures in offshore areas where extensive use is now difficult due to strong waves, thereby creating a calmed-water area. Table 6 shows the results of case studies of seven selected sea areas that differ in natural conditions and in social/economic conditions.

As an example of large-scale offshore artificial islands, Figure 5 shows a concept of utilizing a calmed-water area 7 km distant from the coast for marine recreation, fish cultivation, and refuge anchorage. As an example of medium-scale islands, Figure 6 shows a concept of utilizing a calmed-water area 3 km distant from the coast for marine recreation. Full advantage is taken of the area's location.

Children's image of future offshore artificial islands

We asked one hundred children to imagine an artificial island suitable for the 21st century. These children, who will live their adult lives in the society of that century, are fourth, fifth and sixth-grade pupils in primary school, and they live in inland areas. Typical examples are Figure 7, which shows an undersea city, and Figure 8, which depicts a realistic city reflecting aspects of today's world along with dreamlike transportation facilities. Both images are warm and heartfelt, and they give us a fresh impression of the possibilities that lie ahead.

Table 4

Schemes for Six Offshore Artificial Islands in the Future[1]

Items \ Schemes	International distribution center	Comprehensive leisure land	Marine ranch	Intelligent amenity island	New energy center	Composite (foods, energy) reserve base
Location conditions	Pacific coastal area and neighborhood of consuming area	Neighborhood of large city	Coastal area facing the open sea	Neighborhood of large city	Neighborhood of large city	Inside-bay area near consuming area
Distance from shore	10 km	5-10 km	3-6 km	3-5 km	Neighborhood of land	Several km
Size	500 ha	820 ha	288 ha	2,300 ha	2,000 ha	270 ha
Structural type	Reclamation/ floating or soft-grounding type	6 units of structures mentioned at left	Floating	Reclamation: 3 units/ Floating: 3 units	Reclamation	Reclamation
Access	Sea/air routes	Sea/air routes and railways/ highways	Sea route	Bridge and tunnel	Bridge and tunnel	Sea route
Projected population and capacity	Hinterland: 10 million	200,000-300,000	Hinterland: 2 million	Habitants: 120,000 Daytime population: 150,000	300,000	300,000 tons 5 million kl
Function and facility	• Port/harbor facility • Airport facility • International market (vegetable, fishery products, fruit, meat) • Hotel • International convention hall • 5,000 workers	• Port/harbor facility • Airport facility • Parking lot • Marina • Amusement center • Sports facility • Games facility • Tennis ground	• Port/harbor facility • Hatching and fry facility • Intermediate product nurturing facility • Marine ranch • Cultivation facility	• Housing • Business facility • Exchange facility • Information back-up facility • Energy facility • Recreation facility	• Fuel cell • Cogeneration • New energy center • Housing • Business facility • Cultural facility • Park, road	• Grain • Petroleum • Port/harbor facility • Silo • Tank

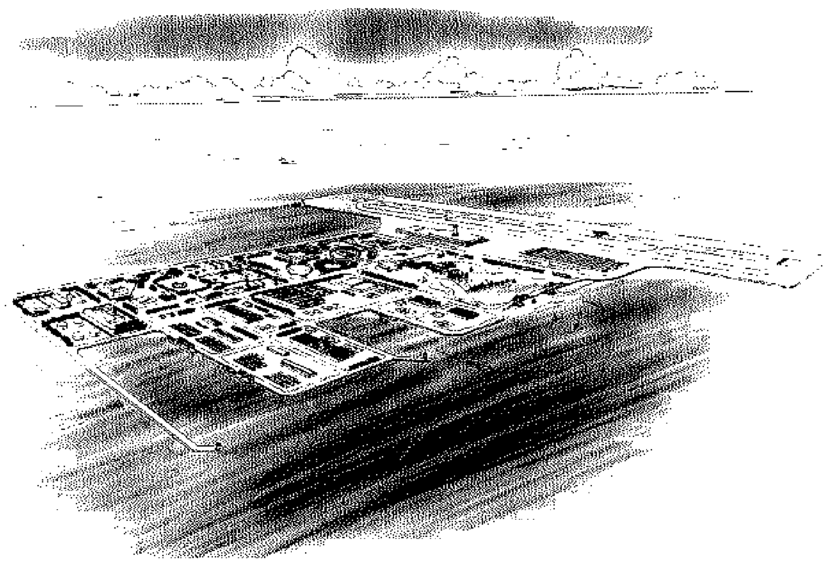


Figure 3. Concept of offshore artificial island (International Distribution Center)

Table 5

Schemes for Four Offshore Artificial Islands in the Future[2]

Item \ Scheme	Space port land	Whale center	International medical port	Back-up city land
Location	Southern sea area near the equator	Coastal area facing the open sea	Network of Asia, North America, Europe, Africa and South America	Neighborhood of large city
Distance from shore		10-20 km		
Size	1,000 ha	300 ha	300 ha x 3 layers, 100 ha (airport)	1,200 ha
Structural type	Reclamation, floating or soft-grounding	Semisubmersible floating	Floating	Reclamation
Access	Sea/air routes	Sea/air routes	Air route	Sea/air routes
Projected population and capacity	10,000	30 whales (humpback and minke)	30,000	One million (victims of disasters)
Function and facility	• 5,000 m^2 x 2 • ELV and RLV base • Research/testing/ training facility • Observation/com-munications facility • Port/harbor facility • Power station	• Partition facility (acoustic or electric barrier) • Feed supply facility • Nurturing facility • Control/ observation facility	• Advanced medical center • International joint research center • International internal organs bank • International medical information center • Rehabilitation center	• Victims refuge space • Power station • Sewage treatment facility • Waste incineration facility • Food-related facility • Administrative facility • Business facility

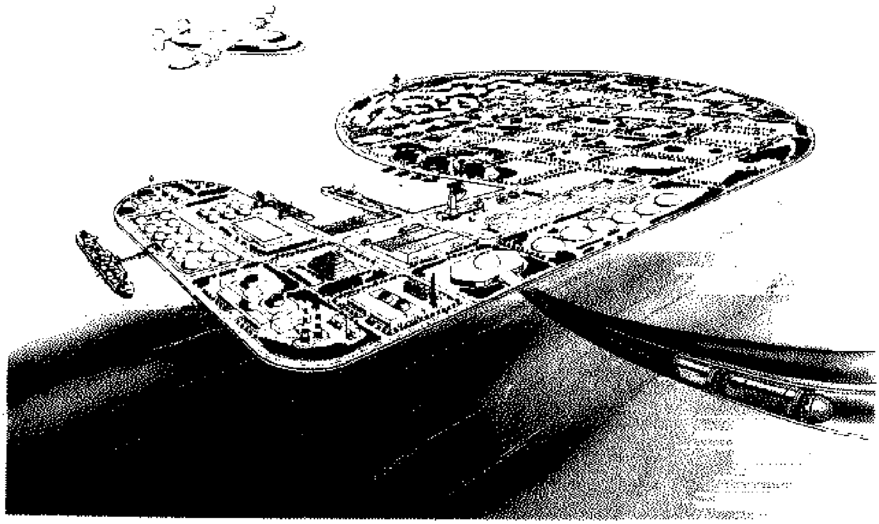


Figure 4. Concept of offshore artificial island (Back-up City Land)

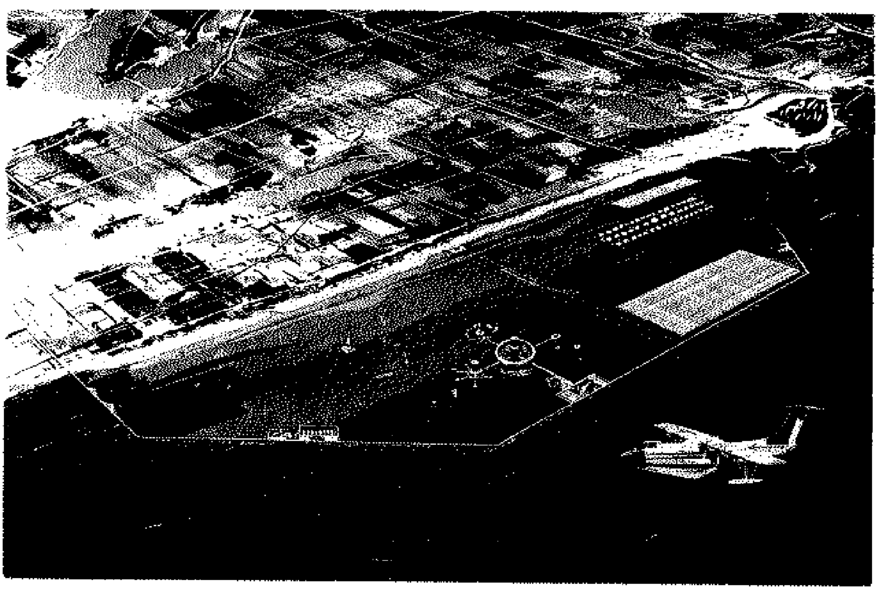


Figure 5. Concept of calmed-water area utilization of Sea of Kashima (Kashimanada)

Table 6

Case Studies for Seven Calmed-water Areas

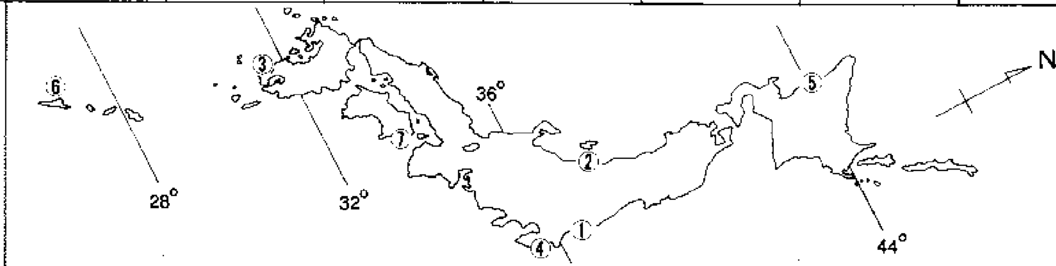
Item / Location	① Kashimanada	② Niigata	③ Fukiagehama	④ Kuju-Kuri	⑤ Rumoi	⑥ Motobu	⑦ Old Yoshino River
	 						
Sea area	North Pacific Ocean	Mid-Japan Sea	Eastern East China Sea	North Pacific Ocean	North Japan Sea	South Pacific Ocean	Mid-Pacific Ocean
Land area	Neighborhood of large city	Neighborhood of local nucleus city	Local city	Neighborhood of large city	Local city		
Distance from shore	7 km	4 km	8-10 km	12 km	0.7 km	3 km	3 km
Water depth	20-25 m	40 m	30-40 m	25-30 m	14 m	50 m	18 m
Size	9,000 ha	3,600 ha	11,000 ha	3,750 ha	67 ha	980 ha	800 ha
Utilization	• Marine recreation • Fish cultivation • Refuge anchorage	• Same as left • Research and education • Power station	• Same as left • Research and education • Airport	• Same as left • Research and education	• Same as left • Fishery product processing facility • Seafood restaurant	• Marine recreation (offshore hotel, resort facility, culture center)	• Marine leisure facility (science, adventure, fantasy)
Advantage	• Close to Narita International Airport • Tieup with local area's scheme	• Coastal erosion prevention around river estuary • Impact on regional economy in winter season in particular • Use of slag for island fill	• Research town in collaboration with Southeast Asian nations • Favorable impact on regional economy	• Responding to leisure demand from Tokyo Metropolitan area • Strengthening of local position as a good fishery area	• Development of regional economy by fishery product processing	• Year-round marine leisure	• Responding to leisure demand from Kinki area • Close to Kansai International Airport

Figure 6. Concept of calmed-water area utilization at Motobu, Okinawa

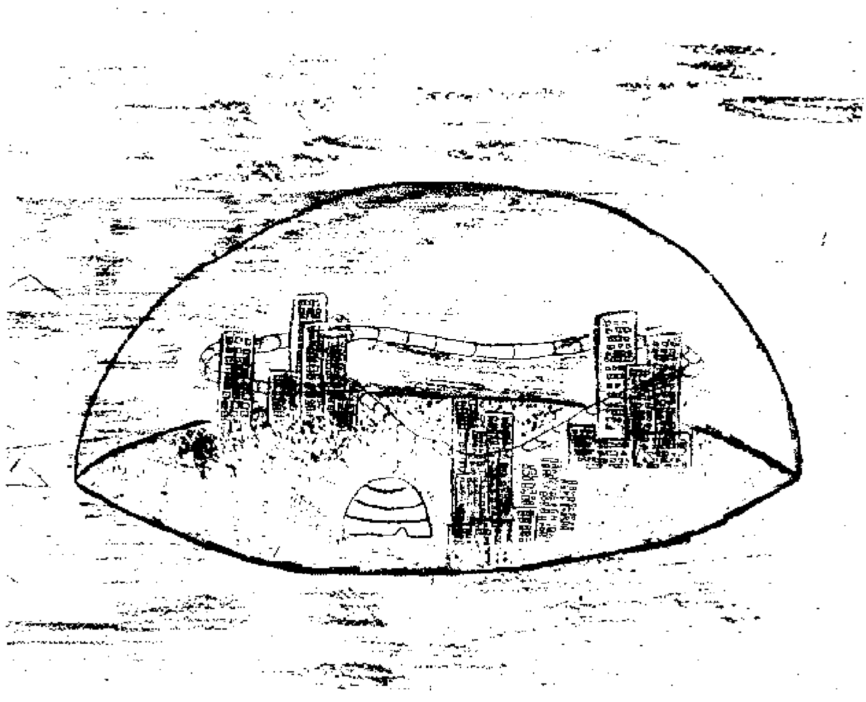


Figure 7. Future image of offshore artificial island conceived by children (Underwater City)

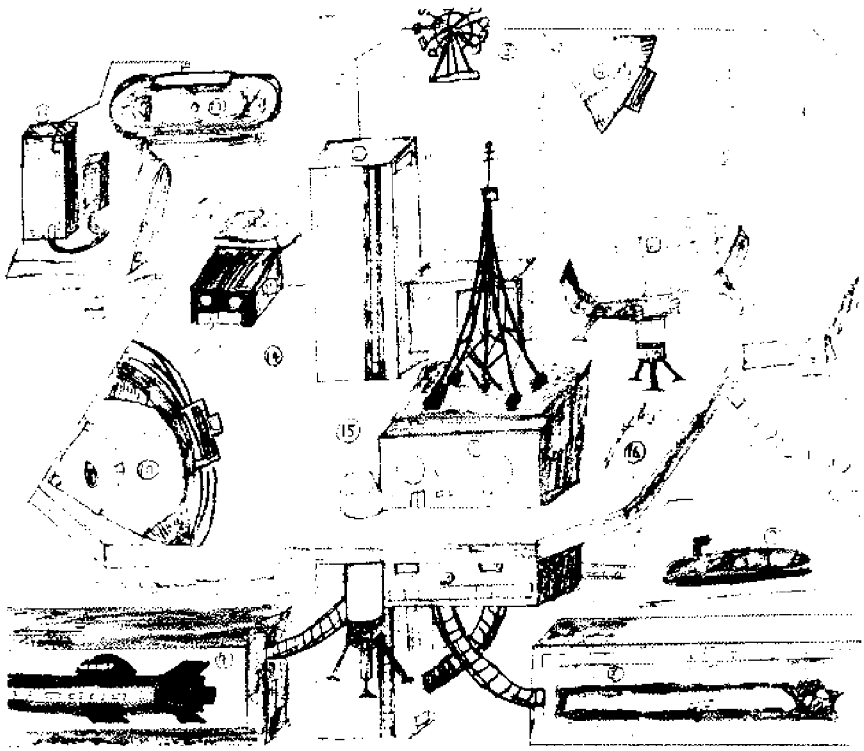


Figure 8. Future image of offshore artificial island conceived by children (City)

CONCLUSIONS

Conventional space utilization of coastal areas poses various problems such as limited space on or near the coast itself, concentration of population and industry, environmental deterioration, and competition among those wishing to utilize the space available in the area. In response to these problems, the offshore artificial islands concept has been proposed as a system for the development of offshore areas that creates new functional space — including the calmed-water areas in the surrounding sea area — by constructing artificial islands at a distance from existing land areas. This system is superior to offshore space utilization through reclamation of coastal areas or coastal artificial islands, and it indicates the future direction of space development and utilization in Japan.

Characteristics of offshore artificial islands

Construction of offshore artificial islands has the following characteristics, which enable this approach to meet emerging social needs.

1) It promotes space utilization by making available to the utmost degree the useful characteristics of the sea area involved while conserving the environment of the national land and creating new national land.

2) The utilization of offshore space in an offshore island project facilitates three-dimensional use of such space, creating a new sphere to ensure versatile utilization.

3) There is great freedom of selection in determining the location, size and shape of the space to be utilized.

4) Offshore artificial islands have little impact on the use of adjacent onshore areas along the coast, and they create useful calmed-water areas between the coastline and the islands.

5) Existing coastal areas can be vitalized by integrated and comprehensive use of these onshore areas, the calmed-water areas, the offshore artificial islands and the surrounding sea area.

6) An offshore area can readily provide sites for facilities that are difficult to place in adjacent, existing onshore areas, which are usually limited in space and already congested. Offshore artificial islands will thus contribute to improvement of the environment, prevention of disasters, and upgrading of scenery in nearby existing onshore areas.

7) Construction of offshore artificial islands has become feasible from the viewpoint of the technology required: port construction techniques and shipbuilding techniques that have been developed and refined by experience in reclamation of coastal areas and construction of coastal artificial islands.

Means of realizing the concepts of offshore artificial islands

To realize the concepts of offshore artificial islands, various tasks arise according to the content of each concept.

1) At present, many rights and regulations (fishery rights, regulations for port and harbor districts, national park regulations, etc.) are already in place. When use of new offshore space begins, disappearance of some rights or changes in regulations are required in most cases. The extremely long time and high cost of effecting such changes are obstacles to implementing the concept in many cases.

2) Because many regulations or laws bear on offshore space utilization, there are many supervisory government offices and management bodies involved. In many cases, therefore, adjustments and completion of many procedures are necessary if the concept is to be realized.

3) There may also be a major problem related to the sharing of expenses in realizing offshore artificial island projects. The problem arises if the construction period must be extended or plans must be changed due to imbalances that may occur between public investment in infrastructure development and private investment in the project.

4) There may be problems from the viewpoint of environmental preservation — in particular deposition and erosion due to changes in tidal currents in the surrounding sea areas, and negative effects on marine life due to the construction of offshore artificial islands.

5) From the viewpoint of technology, the problems related to environmental control and management are rather greater than those of construction.

To overcome these difficulties, the following steps will be required.

1) Flexible interpretation of laws, regulations and procedures or enactment of new laws so that integrated processing of regulatory requirements is possible.

2) Establishment of a cooperation system such as the third-sector system for carrying out such projects, in which the government, local public organizations and the private sector are united in carrying the project forward.

3) Economic support by the government for tapping the vitality of the private sector in such projects. This includes, for example, subsidies to cover part of the interest cost of borrowed money, and preferential taxation arrangements.

4) Introduction of private-sector funds through underwriting and absorption of national bonds or local-government bonds.

5) Local community-participation projects to ensure smooth progress in building local society and to promote consent by local communities.

6) Technological development aimed at reducing the construction cost of offshore artificial islands.

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Wakayama Marina City Project

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At Wakanoura Bay, in the middle part of Wakayama-Shimotsu Port, Wakayama Marina City Project has been under construction. For the Wakayama Prefectural Government, the development of a marine resort making use of the long coastline and ocean space is one of the most important policies.

Wakayama Marina City is expected to play a leading role developing the Wakayama Prefecture toward the coming 21st century. The opening of Kansai International Airport in the vicinity will give an especially important role to this project.

This project is executed under a partnership between the public and private sectors. On the basis of this principle, the infrastructure is constructed by the public sector, and after it is completed, the area will be operated with the vitality of the private sector.

This project aims at realizing an international urban resort complex with a marina on a reclaimed man-made island, located 150 m offshore with an area of 49 hectares. This Wakayama Marina City Project stresses the advantageous utilization of sea and waterfront, and offers various chances for enjoying marine life. The island produces a long waterfront and the marina is a base of marine leisure. Moreover, for creating waterfront amenities, the breakwater and revetment are designed for people to enjoy the sea, and creeks are planned in the island. A fisherman's wharf where marine products from the surrounding sea are treated, and a passenger boat terminal that is a new gateway to Wakayama from the ocean are also planned.

International Perspectives on Coastal Ocean Space Utilization
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MARINE RESORT DEVELOPMENT IN WAKANOURA BAY

Wakayama Prefecture, located in the southwestern part of Kii Peninsula, enjoys a mild climate throughout the year and has long daylight hours.

Also called "The Wood Country," it is blessed with a rich natural environment, with resources such as mountain ranges abundant in foliage, clean ample water, a 600 km-long coast bordered by the Kuroshio current, hot springs and a wide variety of animals and plants. These natural treasures provide people with the pleasures of sightseeing, the study of nature and academic research.

With the improvement of Japanese living standards, its changing social values and the increase in leisure time, more and more people will look towards the natural treasures in Wakayama Prefecture as being important for preservation. To accommodate this preservation, the resources must be utilized as efficiently as possible, while still encouraging the development necessary to bring the coastal region into the 21st century, as Japan's new frontier.

Against this background, the need for a program such as a development plan for Wakayama Prefecture becomes very clear. This program will fulfill both the need for preservation and efficient development of the coastal region. The benefits will be numerous and include the creation of convenient and safe facilities, the establishment of an economic base for setttlement of the prefecture's population, the introduction of new industries through decentralization, the expansion of health-related facilities and the conservation of this region's natural environment, which are the source of its citizens' creativity and sensitivity. By offering these benefits the plan achieves a careful balance between the need for development and preservation. With these benefits in mind, we have designated the "Techno and Resort Plan" as the core of "Wakayama Prefectural Government's Long-Range Development Plan."

Wakanoura Bay is located in the northern part of Wakayama Prefecture, and is located next to the metropolitan area of Osaka. Because of its close proximity it is expected to benefit the most from the development of the Kansai International Airport. The benefits derived from improved access because of airport construction, coupled with the historical beauty of this region and comparatively calm bay area, makes Wakanoura Bay an ideal location for an international marine resort. This bay is in the area of Wakayama Shimotsu Port. This port has 120 km^2 area; in the northern part, steel is handled and in the southern part, oil is. Wakanoura Bay is located in the central part of the port area, and is suitable for recreational activities from the viewpoint of functional allotment in the port.

On the other hand, the Ministry of Transport established "The Port Development Plan Toward the 21st Century" in May 1985, and has provided a clear outline for the future development of the ports and harbors in Japan. The plan's objectives are to create port and harbor space integrated with various human activities, and at the same time to create a network of interlocking ports and harbors, designed to meet the changing socio-economic structure in Japan. The port and harbor space integrated calls for ports to be designed as spaces with amenities that provide a variety of facilities, ranging from bathing, salt-water fishing, yachts and other pleasure boats, marina hotels, restaurants and leisure facilities.

The off-shore artificial island project, Wakayama Marina City, has been planned in Wakanoura Bay. The significant merits of the comprehensive utilization of Wakanoura Bay are the following:

i) The area around the Wakanoura Bay has a beautiful shoreline with a variety of natural environments, ranging from sandy beaches to rocky cliffs. The calm waters are excellent for yachting and boating. The area is adjacent to the Kyoto-Osaka-Kobe district, and tourism and transportation will improve with the development of the proposed Kansai International Airport.

ii) With the cooperation of the various recreational facilities for tourism, the development of a strong diverse tourism industry will capitalize on tourist attractions surrounding the bay such as Wakayama Marina City, the natural beauty of this shoreline and sea, the Kataonami beach, Waka Park and the scenic fishing towns of Wakanoura, Saigasaki, and Tanoura.

iii) The conversion of the regional economic structure from that of primarily heavy industry to a service oriented infrastructure, will in time encourage the investment of information and high-tech industry into this area. This shift in industry will revitalize the local economy and prepare the area for the near-future demands for information and service oriented industries.

THE OUTLINE OF WAKAYAMA MARINA CITY

This Wakayama City Marina has been planned with 5 targets:

- Creation of a Marine Resort Complex
- Promotion of Economic Revitalization of the Prefecture
- Contribution toward Prefectural Culture and Its Enhancement
- Creation of a Major Sports Center
- Creation of Family Land and Restful Environment

This project will have a total area of 65 hectares, of which 49 hectares will be reclaimed by filling up an offshore area to form a man-made island. The sea area about 150 m wide sandwiched between the man-made island and the existing shoreline will be integrated with natural shorelines and the island shorelines to create a unique recreation-oriented space.

The proposed marina, which will form the core of the man-made island, will be capable of accommodating nearly 1,000 yachts and other pleasure boats and will constitute part of the marine resort complex consisting primarily of sports facilities, a fishermen's wharf, commercial establishments, accommodations for tourists and holidaymakers and other amenities. According to plans, the resort complex could have three million visitors annually, with part of the island inhabited by 4,000 permanent residents.

The man-made island will be linked to the existing city area by two access bridges, one 410 m long and the other 280 m long. A north and a south breakwater with a combined length of 920 m to shelter the marina, passenger boat wharf, marina basin and other harbor facilities are also planned.

The man-made island will consist of such developments as 39.3 hectares for recreational facilities featuring the scenic natural environment of Wakanoura Bay, 3.2 hectares for construction of a wharf providing direct access to the Kansai International Airport currently under construction, which is expected to contribute toward promoting fisheries and other local industries, 2.3 hectares for facilities dedicated to international cultural exchanges in an effort to keep abreast of the trend toward internationalization of the various aspects of national life, 1.2 hectares for park construction with a view to giving landscaping effects to the man-made island and providing a restful environment for visitors, and 2.9 hectares for road construction.

The planned recreational complex, accounting for approximately 80% of the artificial island, will comprise a marina, residential area, accommodation for sightseers and holidaymakers, sports and cultural facilities and commercial establishments, making best use of its characteristic surroundings.

The wharf area will include a fishermen's wharf, a major attractive facility in the island. The facilities dedicated to disseminating the prefecture's cultural traditions and contributing toward international cultural exchanges are planned for the area set aside for this purpose.

Nearly 20% of the man-made island will be covered with green foliage so as to contribute toward harmony with the surrounding natural environment.

The Wakayama Marina City, featuring an offshore man-made island, is characterized by the concept of achieving the maximum possible development and utilization of the potential of the sea and waterfront areas involved.

The island Wakayama Marina City is to be surrounded by the sea on all sides, in addition to two waterways planned in the island. Thus, the reclaimed island will have nearly 8,400 m of shoreline with 500 m of mooring facilities, 900 m of revetment for the marina, 250 m of revetment for the park, 1,400 m of revetment for the two waterways and others. The crosssections of the shoreline are designed with consideration of waterfront amenities.

In addition, the two proposed breakwaters with a total length of 920 m fronting the Wakayama Marina City has been designed, using computer graphics, as the first trial for a breakwater with amenities. Distinct from conventional breakwaters whose primary functions are to shelter harbor basins and navigable waterways against waves, the breakwaters planned for the Wakayama Marina City are intended to perform the additional functions of permitting visitors unobstructed and safe access to the resort complex and safeguarding their recreational activities in its offshore areas. In the proposed breakwaters, the superstructures are designed to provide adequate spaces accessible to visitors and protect them from exposure to direct sunshine and splashes from waves. The design also makes provision for small boats.

Planned for the coastline running along the access road connecting the existing city area to the man-made island are stepped revetments, promenades and other waterfront facilities which will be conductive to the enhancement of the environmental value of the Wakanoura Bay area.

On the Wakayama Marina City Project, environmental impact assessments using simulation models and other methods were undertaken at various stages. It was concluded that the project will produce only minor impacts on the natural environment of the project area. During the execution of the construction works monitoring is being performed to prevent environmental disruption in the project area.

IMPLEMENTATION OF THE PROJECT

The Wakayama Marina City project aims at realizing a new type of urban resort city, with the marina as the center of a reclaimed artificial island. It is required that the improvement of necessary infrastructures and various activities on the island should be developed under a common concept. This common concept will involve the full utilization of public and private resources, with due respect to public interests and relative market values. The basic ideas are as follows:

i) Basic facilities will be provided by the public sector and made use of by private sector's vitality.

ii) The construction, maintenance and management of the project must be made attractive to the private sector, as a whole. This will result in high-quality services and facilities being made available to the public via the project.

iii) The private and public facilities will be smoothly operated.

iv) In implementing this project, the final utilization of the area must be promoted in an orderly manner with due consideration of the interests of related activities such as fisheries, marine sports and vessel navigation.

The project has been promoted through the concerted efforts of the Wakayama Prefectural Government and Matsushita Investment and Development Co., Ltd. , a private firm closely associated with the prefecture. A preliminary study of the feasibility of a coastal resort development in Wakayama-Shimotu Port was undertaken by the Ministry of Transport, the Wakayama Prefectural Government, and the Wakayama City Office in fiscal 1987. This was followed by a series of comprehensive technical discussions and deliberations by an ad hoc study committee composed of scholars and experts in related disciplines, and common local interests.

Consequently, the Wakayama Marina City Plan was officially approved in November 1987 as a part of the Development Plan of Wakayama-Shimotu Port under the Ports and Harbors Law. A reclamation permit was granted for the project in January 1989 under the Public Water Surface Reclamation Law. The construction stage began in April 1989. Offshore works and access roads, including bridges construction, are currently underway, and reclamation work has started.

The breakwaters with amenities are being built by the 3rd District Port Construction Bureau, Ministry of Transport. Wharves, bridges, roads, facilities for amenities and the reclamation are under the control of the Wakayama Prefectural Government. A part of the recreation area is being reclaimed under the control of Wakayama Marina City Co., Ltd., a specially established public-private sector, for the first off-shore man-made island-project under the Coastal Space Creation Undertaking Program, initiated by the Ministry of Transport in fiscal 1989.

Overall, the Wakayama Marina City Project has been promoted by the concerted development efforts of the central and prefectural governments and the public-private sector joint venture for the creation of an international urban resort complex island in harmony with the surrounding sea.

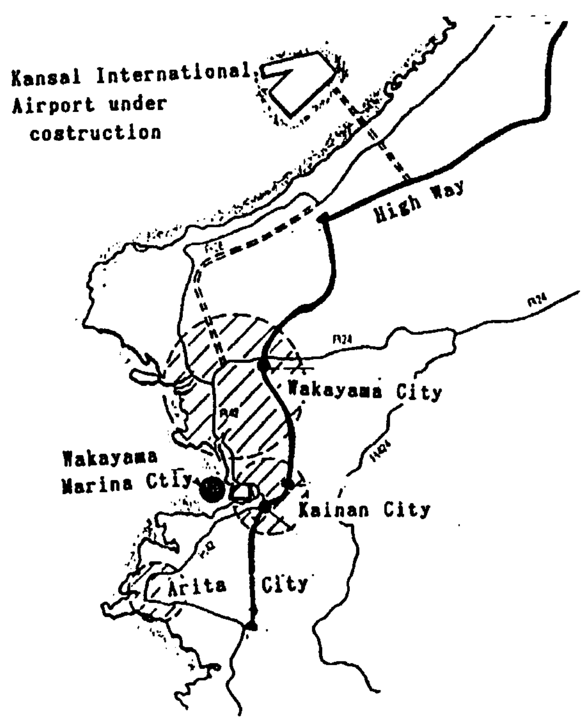

Figure 1. Location of Wakayama Marina City

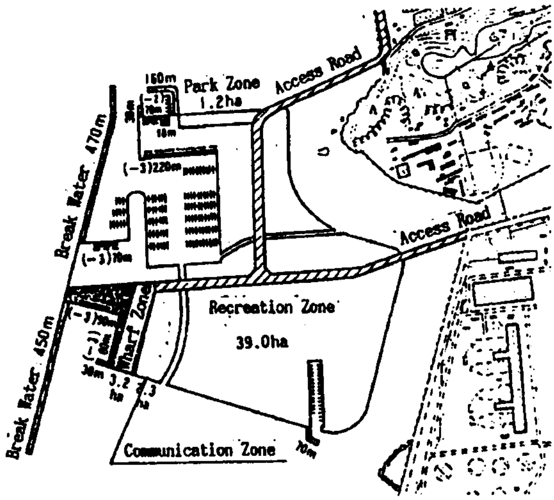

Figure 2. Port Planning of Wakayama Marina City

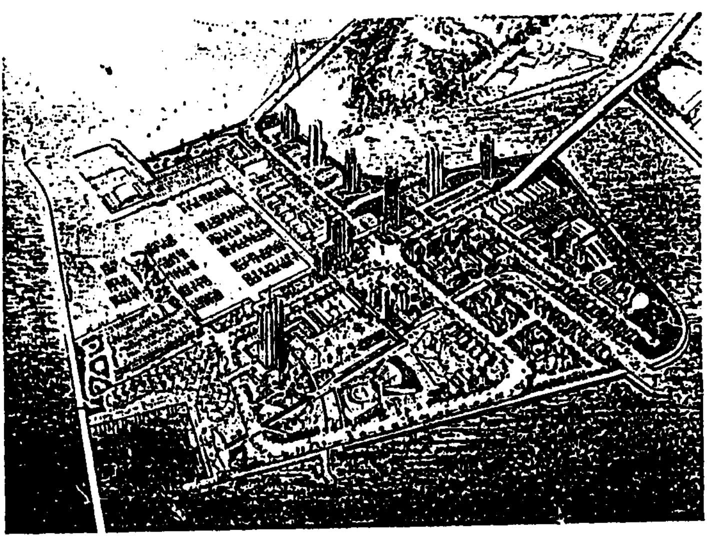

Figure 3. Image Perspective drawing of Wakayama Marina City

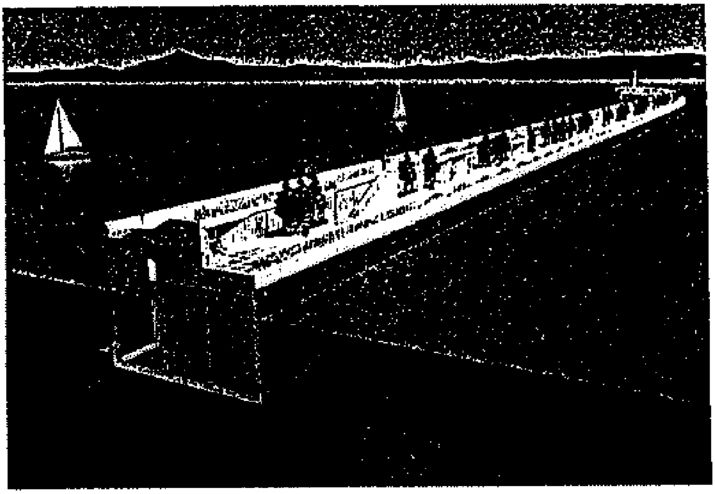

Figure 4. Image concept of breakwater with amenities

(Edited by P.M. Grifman)

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Implementing Cost-Effective Environmentally Safe "Harbor of Refuge" Marinas

Jim Parks
President, DYNEQS Ltd., Tampa, Florida

ABSTRACT

The increasing numbers of ever-larger ocean-going recreational boats has brought pressure to establish closely-spaced, safe "harbor of refuge" marinas along coastlines all over the world. However, in many areas environmental concerns have delayed or prevented their creation. For example, developing new marinas involves dredging channels and basins that are usually protected with jetties, moles and breakwaters — and such structures are now known to damage downdrift beaches.

Newly developed improved methods for fluidized sand bypassing offer advantages that may reduce the objections. Feeding sand from one or more linear fluidized sand traps to a fixed jet eductor pump will significantly reduce costs (to well below that of periodic conventional dredging over a 20-30 year period) and prevent downdrift beach erosion through bypassing nearly 100 percent of the longshore drift. Fluidization is the addition of excess water to form a sand/water slurry that flows down a slight slope and is pumpable — the concept is simple but cost-effective implementation is somewhat complex. Permanent pump/pipe installations qualify for various types of long-term financing.

Examples of planned fluidized sand bypassing installations demonstrate some of the possibilities.

International Perspectives on Coastal Ocean Space Utilization
Phyllis M. Grifman and James A. Fawcett, Editors

INTRODUCTION

Recreational boating is rapidly becoming a dominant factor in coastal zone usage. Nationwide, more than 100,000 new boats join the recreational fleet every year — and the cumulative total of boats longer than 16 feet now numbers in the millions. Florida alone has over 800,000 registered boats.

Due to federal budget deficits and attempts to balance the budget with decreased services, the U. S. Army Corps of Engineers (USACE) has recently announced that it will no longer be responsible for maintaining navigable depths in channels for inlets, passes and harbor entrances that do not have a significant commercial shipping or commercial fishing impact. In Florida, only a handful of inlets and harbor entrances remain in the Corps' area of responsibility, and the majority of the state's 50 or more inlets will be maintained solely by local taxing districts (e.g., Sebastian Inlet, Hillsboro Inlet and the several west coast inlets in Manatee, Sarasota, Charlotte and Lee Counties under the jurisdiction of the West Coast Inland Navigation District — the only regional inlet district in Florida) with or without help from the State of Florida (itself operating under budget cutbacks due to major deficits). Many coastal Florida counties are seeking long-term inexpensive solutions to inlet shoaling problems, in order to keep the large boating public happy.

This problem is world-wide in scope — in France, the SIVOM COTE SUD (Syndicat Intracommunal a Vocation Multiple Cote Sud) recently stated in a document titled *Program: Needs and Requirements* that "a sense that part of the future of the resort towns (Capbreton, Hossegor, Seignosse, Labenne) relies on the improvement of the Capbreton north and south beach situation and even more on the Capbreton marina accessibility for boaters" [personal communication by translator].

Existing marinas serving the recreational boater are becoming overcrowded — and attempts to build new marinas are running into severe and increasingly stringent environmental restrictions. Equally important for the increasing number of inexperienced boaters is the availability of "harbors of refuge" — defined as an all-weather protected anchorage or dock accessible within a few hours from any coastal area frequented by recreational boaters (which translates to a sheltered harbor every 15-20 miles [24 to 32 km] along the shoreline). This frequency is met along some parts of the U.S. coastline, but not others (e.g. Gulf Coast of Florida north and west of the Tampa area; much of the Texas Gulf Coast; and the Pacific coast of California north of San Francisco, Oregon and Washington). Many harbors and marinas do not qualify as "harbors of refuge" because much of the time their entrances are (partially) blocked with shoals, or the channel has migrated laterally to the point where channel markers (if they still exist) are useless.

BACKGROUND

As part of an effort to update the existing design criteria for small boat harbors, the U. S. Army Engineer Waterways Experiment Station has compiled an inventory of more than 600 small boat harbors constructed and/or maintained by the USACE.[8] Using this data base, a classification scheme of harbor types has been developed:[8]

a. Harbors constructed seaward of the shoreline and protected by breakwaters;
b. Harbors constructed seaward of the shoreline and protected by breakwaters, with inner basins built inland through the shoreline;
c. Harbors constructed inland with an entrance through the shoreline;
d. Harbors constructed with rivers entering into them or inside river mouths; and
e. Harbors constructed in inlets.

In the past, most marinas have been built in situations where they can take advantage of natural protection (types d and e in the above classification). However, there are not enough of these to satisfy increasing demands for boat slips and the needs for "harbors of refuge." Consequently, the majority of new marinas are of types a, b and c, which have less restrictions as to their location.

A common problem to all small boat harbors is a tendency to develop shoaling in the entrance channels. Most harbors and marinas are too small in area to have an adequate "tidal prism" (volume of tidal exchange through the entrance channel) for "self-scouring," particularly at the mouth of the channel. This generally results in frequent shoaling and meandering (lateral migration of the channel). The standard remedy is conventional dredging, with all of its attendant problems (high cost; inavailability when most needed — immediately after a significant storm event or in early spring when everyone wants a channel dredged at the same time; and deleterious environmental side-effects).

Some new marinas (type c) are being built by digging out a new harbor basin with land-based equipment, with the final step being "breaking through" the entrance channel to open water. At Hilton Head Island, a gate-lock was installed to maintain the water level in the boat basin, allowing boats to enter or leave only at certain tide levels.

In those situations where the entrance channel is "protected" by jetties, another common problem is the interference with longshore drift and consequent down-drift beach erosion.

DESCRIPTION OF FLUIDIZED SAND BYPASSING

The process of fluidization has been well described in a series of reports from the Lehigh University group.[16,17,18] The idea came from New Zealand,[6] although U.S. Patent #510,713, issued in December 1893 to R.M. Scott of Sydney, Australia, describes a surprisingly similar method. The Scripps Institution of Oceanography group also picked up on the New Zealand concept[7] and developed the "duct-flow crater-sink fluidization" process.[1,9,10] Others have discussed various aspects of fluidization.[2,3,4,12,13] Research on fluidization is continuing at Lehigh University.[11,19]

Any beach-quality sand removed from a channel by any means in Florida must be placed back on a nearby eroding beach. The original channel fluidization concept[5] of allowing the sand to flow downslope to offshore deeper water (and thus be lost to the littoral drift system) has been modified to include pumping the fluidized sand[14] to downdrift beaches. The fluidizing pipes are sloped from the distal ends to the mid-length position where a jet-eductor pump located immediately above the fluidizing pipes moves the sand through a discharge pipe to the downdrift beach.

Fluidization is achieved by pumping clear water into a buried perforated pipe (Figure 1). The upward flow of excess water fluidizes the sand and maintains the state of fluidization (about a 50-50 mixture of sand and water).

(about a 5Ø-5Ø mixture of sand and water).

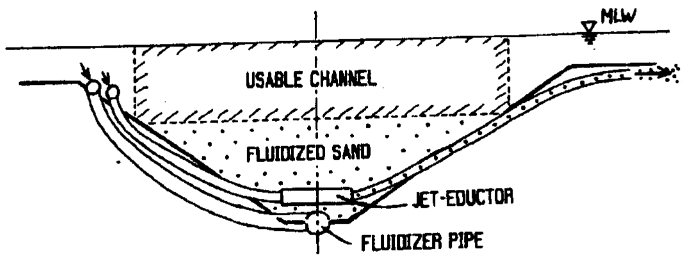

Figure 1. Cross-section view of fluidized channel

With fluidization in a linear trench, the fluidized sand/water slurry can be transported laterally for significant distances. From a mid-length pump location the fluidizer pipes extend in both directions as much as 100 meters, and are sloped slightly upward away from the pump. Fluidization is first initiated in one direction with the full flow capacity of the clear water pump; then a part of the clear water stream is diverted to a fixed jet-eductor pump to pump fluidized sand out of the "trench."[14] As the level of fluidized sand is pumped down in a local "cone of depression," lateral flow will occur along the length of the trench (Figure 2).

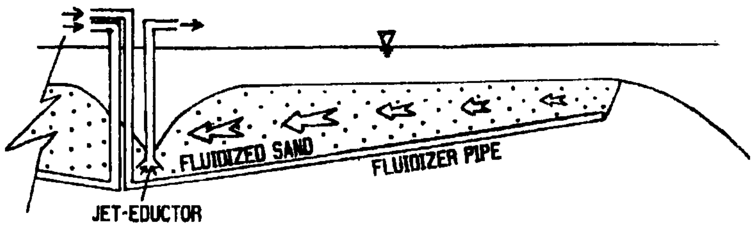

Figure 2. Longitudinal section of fluidized channel

This effectively "feeds" the jet-eductor pump from a much broader area than its own small diameter circular crater. As the sediment has already been fluidized before the jet-eductor pump is activated, less water flow and less energy than usual will be required to operate the jet pump. A fluidized trench (channel or sand trap) as long as 200 meters (650 feet) can be maintained from the one central pump station.

The new technology of fluidization "moves the sand to the pump." While it is fluidized the sand/water slurry flows down a gentle slope to a point at mid-length from where it is easily pumped to nearby eroded beaches — a form of sand bypassing. The permanent installation of pipes and pumps eliminates repeated mob/demob costs, and allows long-term low-cost bond financing. Fluidization does not cause turbidity or disturb bottom fisheries. Pumps mounted on pilings and deeply buried fluidizer pipes are independent of weather. The system can operate during and soon after storms when most of the sand transport occurs. Channel clearing can be frequent, as often as once or twice a month, thus effectively "fixing" the channel location (Fig. 3). Permanent and/or centerline-range channel markers can be used, thereby enhancing boating safety.

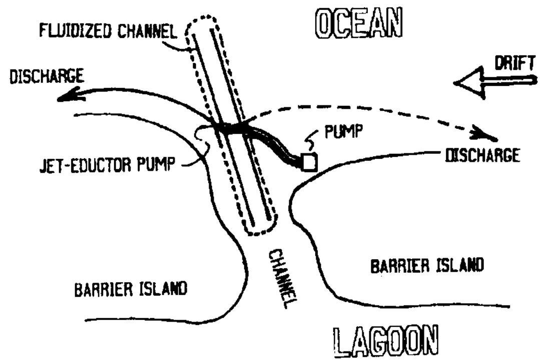

Figure 3. Map view of fluidized channel

A number of configurations of a fluidizing system within and around an inlet are possible. Fluidized sand bybassing uses the boat navigation channel as the sand trap, with a linear fluidization pipe feeding the sand along the channel bottom to a midlength jet-eductor pump and its crater-sump . With a permanent pipe system and a dedicated pump/engine the channel can be cleared as frequently as needed independent of weather to handle the volume of gross littoral drift impacting that channel. One or more fluidizer lines can run along the axis of the inlet. Sand from the channel is pumped to nearby beaches.

Fluidized sand traps can be located outside the channel on the updrift side. An array of fluidized sand traps can be placed in the offshore ebb-delta accumulations or in the fillet updrift of a jetty and bypass or "recycle" sand back "updrift" if needed. The total capacity of such an array of fluidized sand traps can be as large as several thousand cubic meters, and the trap can be "pumped out" repeatedly, even during and shortly after storm events. Pump rates of 100-200 cubic meters per day, operating if needed nearly continuously for a significant number of days per year, can bypass several tens of thousands of cubic meters of sand per year from a combined channel and outside the channel array.

PLANNED INSTALLATIONS IN 1991

Flag Harbor Yacht Haven, Chesapeake Bay (Figure 4). The jettied marina entrance develops a shoal no more than 300 feet wide that requires dredging every spring. Plans are underway to install a fluidized sand bypassing system in the spring of 1991 using the channel as the "sand trap".

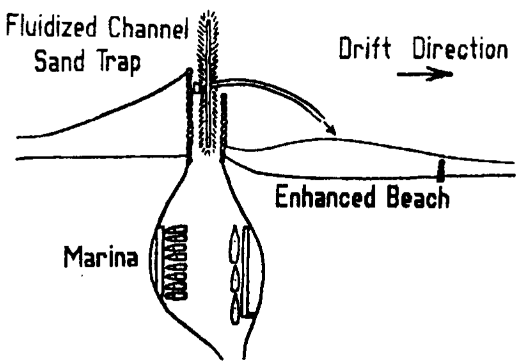

Figure 4. Sketch map of Flag Harbor Yacht Haven channel

Boucarot Passage, Capbreton, France (Figure 5). This jettied harbor entrance on the southwest Atlantic coast of France also requires frequent dredging to maintain navigable depths for the passage of recreational yachts. Fluidized sand bypassing, using the channel as a "sand trap," is being considered by harbor authorities.

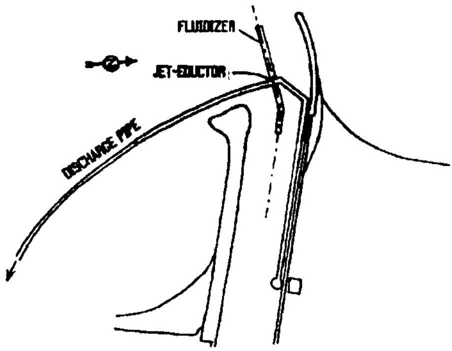

Figure 5. Sketch map of Capbreton harbor channel entrance

Mexico Beach Inlet, Florida Panhandle. Because of a large annual littoral drift, this inlet requires almost continual dredging: a fluidized sand bypassing proposal is under review by city authorities. In this case, the sand trap will be outside (updrift) of the channel.

DISCUSSION

One of the difficulties in the siting of new marinas and small boat harbors to provide adequate number and spacing of "harbors of refuge" for recreational boats is the concern of environmentalists with potential effects on downdrift shorelines. This concern can be made less objectionable by the application of methods for maintaining navigable channel depths that do not aggravate downdrift beach erosion. The new technology of fluidization, and specifically fluidized sand bypassing, can achieve this in a cost-effective manner.

The concept of fluidization is relatively simple. Its implementation, particularly as fluidized sand bypassing, is somewhat more complex, and the design is site-specific to each situation. There are many possible configurations for fluidized sand bypassing systems, and they can be tailored to fit specific needs.

New improved methods for burying the fluidization pipes and for operating the system with smaller capacity pumps have significantly reduced costs. The permanent system, composed of pumps, pipes, valves, controls, etc., can qualify for long term bond financing, similar to that for sewer and potable water systems. Annualized costs are projected to be less than those for periodic conventional dredging.

SUMMARY AND CONCLUSIONS

1. Closely spaced "harbors of refuge" are needed for recreational boats along all coastlines of the world.

2. Fluidized sand bypassing, with "sand traps" located either in the boat channel, or outside and updrift, can reduce the costs of maintaining harbor entrance channels and alleviate downdrift shoreline erosion.

3. Linear fluidized sand traps feeding sand to a fixed jet eductor pump will reduce costs to less than that of periodic conventional dredging over a 20-30 year period.

ACKNOWLEDGEMENTS

The original research on fluidization that was the basis for the later development of fluidized sand bypassing was financially supported by grants from the Pennsylvania Science & Engineering Foundation and the National Sea Grant Program through the New Jersey Marine Science Consortium while the author was professor of geology at Lehigh University. Later research and development on improved methods of pipe burial has been funded by private resources.

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Benefits of Coastal Region Ocean Theme Parks

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ABSTRACT

Concepts for developing ocean theme parks within any major world harbor or in coastal settings offer many positive benefits for improving the quality of life for local residents and visitors. The creation of an ocean theme park offers synergistic support to many existing businesses, educational institutions, and adds a new source of revenue for regional economies. During construction and operations a park offers employment growth, new demand for education and training, ambiance improvement, a change in business mix, and many esthetically desirable permanent improvements. Most cities with a commercial harbor have an adequate resident market and tourist potential to support an ocean technology, science, and maritime theme park. Opportunities exist for a strong viable business in large, intermediate, and small ocean theme parks — world-wide. Ocean theme parks can be compatible with existing maritime businesses and serve as the catalyst for new business enterprises — both ocean and non-ocean related businesses. Recreation facilities have proven to be a welcome adjunct in a muitiple use marine environment.

INTRODUCTION

Historically, most harbors of the world have commercial and military developments vital to maritime activities, ship construction and their attendant support services. In addition, the same harbors have long served as a key element in regional and world trade. For security reasons these commercial enterprises

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cordoned off their coastal premises to public access. Over time public access to coastal properties became limited and dedicated primarily to single purposes. The concept of multiple use for coastal property is becoming of increasing concern. The public demand for access and a share of the limited coastal property has stimulated the development of new viable businesses that provide public access while continuing to satisfy commercial users.

Maritime market changes have resulted in business closures and concomitant regional decay. Redevelopment of coastal properties has become a new goal for harbor and waterway planners. The multiple use concept has matured rapidly as governments seek to provide a balance among the various commercial and public interests in a limited resource. Recreation facilities are now recognized as a highly desirable component of coastal site redevelopment. Baltimore, Jacksonville, Norfolk, San Diego, Los Angeles, San Francisco, Seattle and cities on the Great Lakes and major waterways, like New Orleans, have ocean-related commercial recreation attractions. These facilities commonly include pedestrian malls containing restaurants, shops, and occasionally an aquarium or maritime museum.

This paper addresses the benefits that can be expected from theme park leisure-time recreational facilities that have an expanded ocean-oriented theme. The ocean theme definition includes all facets of the maritime, marine sciences and ocean engineering. From these three topics alone there springs a wealth of options for designing customized and unique recreational facilities, large and small, for coastal site each selected.

The potential for viable ocean theme parks businesses, large, intermediate, and small, exist at many world locations. Clearly, for each specific site, planning effort needs to be given to: the market, site engineering and environmental constraints, conceptual design, architectural design, demographics, the impact of other local attractions, competition, seasonality, synergism with other businesses, periodic upgrading costs, local labor and professional pool, the projected return on investment, and the benefits to be derived by the local citizens.

Large park concepts suitable for development as year-round attractions within the major world harbors create both a local and a tourist destination attraction with attendant benefits to other businesses, educational institutions, and regional economies. Ocean theme parks of varied attendance capacity can be designed to provide a regional "best fit" and to follow prudent investment guidelines. The synergistic effect of a compatible mix of attractions both create a destination city and provide a significant economic force multiplier that benefits all attractions and the city revenue base. A major attraction, the size of Disney World, created a destination city where vacationers spend their entire vacations. This equates to the capture of a larger percentage of the tourist's discretionary funds that will be spent in the chosen destination city.

WHAT WILL BE THE APPEAL OF AN OCEAN-ORIENTED THEME PARK?

The mystique of the sea continues to be a source of interest for all age groups. Public interest in the exploration of the world ocean on, under, and above the sea surface has been amplified by recent major scientific discoveries. Locating and exploring the ill-fated TITANIC by camera and manned submersibles, excavating the remains of a 3,300 year old shipwreck off Turkey, retrieving the treasure of the galleon ATOCHA sunk in the Florida Keys, probing and examining hot water vent "smokers" at 9,000 feet, descending seven miles to the deepest known depth in the ocean, and uncovering new animals in the deep depths of the sea represent but the tip of the iceberg for discovery and rediscovery. Chances to visit, explore and experience the real world of the sea-going mariner and scientist remain all too limited for the lay public. The majority of lay persons have never been aboard a real seagoing vessel. For those that have there is a desire to return for a visit and likely share the experience with a younger generation or friends. The ocean related topics list for creating entertaining and educational attractions is long and changing dally.

REGIONAL BENEFITS

1. An anchor attraction that will serve as a focus for new business development.
2. An improved quality of life for residents resulting from capital improvements, landscaping, new construction, road and highway improvements, and a higher standard of living.
3. A facility for the use and enjoyment of the entire community.
4. Provides a need for education and vocational training for local residents seeking local employment.
5. A commercial venture that provides practical experience and lifetime employment for a broad spectrum of local talent.
6. An enterprise that is compatible with adjacent harbor city developments and existing businesses.
7. Related business developments are expected to be low polluters.
8. Strong employment base.
9. Excellent source of tax revenue.

For a local economy an ocean-oriented theme park offers economic and employment growth, expanded tax revenue base, ambiance improvement, a change in business mix, enhanced local education and training, desirable permanent improvements, all at minimal financial risk to the community impacted. The regional tax revenue base that can be enjoyed from tourism by state and local jurisdictions is significant. Table 1 summarizes the 1986 level of tourist spending in California and the level of tax revenue that reaches state and local jurisdictions.

Table 1

Tourist Spending in California, 1986

Travel Type of Business	Expenditures ($000)	Payroll ($000)	Employment (Jobs)	Tax Receipts Local ($000)	State ($000)
Accommodations	4,848,235	1190,406	109,294	366,441	44,093
Eating/Drinking	7,707,243	1891,846	208,040	110,386	413,409
Food Stores	771,762	80,154	5,131	10,680	37,810
Auto/Transport	2,086,130	182,445	12,080	14,557	115,687
Recreation	2,396,227	614,050	44,690	0	22,711
Retail Sales	5,569,795	67,1820	53,347	80,032	275,799
State Total	23,379,392	4,630,721	432,582	582,096	909,509

CANDIDATE SITES FOR A WORLD OCEAN CENTER

Throughout the world commercial harbors are experiencing a decline or change in their tradition business mix and historical functions, particularly ship building and ship maintenance. Shoreline buildings and piers have fallen into decay. These areas are candidates for rehabilitation to public recreation and tourism. Most waterfronts with a large established commercial harbor have an adequate resident market and tourist potential to support an appropriately sized ocean technology, science, and maritime activities theme park.

Where in the world can a large and intermediate size ocean theme park be created? There are many city with harbors suitable for the creation of an ocean theme park. Table 2 summarizes cities with suitable harbors and with a resident market of two million or more. Each of these could support a substantial ocean theme park.

WHAT KIND OF A FINANCIAL RETURN CAN BE EXPECTED FROM AN OCEAN THEME PARK?

The demonstrated success of American theme parks is legend. After Walt Disney created his Disneyland in Anaheim, California, he recognized that another larger park could be established in sunny Florida. Disney World and EPCOT have been resounding investment successes. Similarly other U.S. theme parks are enjoying sustained popularity and profitability. Each is experiencing strong attendance (Table 3). Observing that untapped markets elsewhere Disney has created new parks in Paris and Tokyo. Note: no existing major theme park has chosen to focus on an ocean theme.

Table 2

Populations of Cities with Major Harbors

Population				
15 million	10-15 million	5-10 million	3-5 million	2-3 million
Los Angeles	Buenos Aires	San Francisco	Miami	San Diego
New York	Rio de Janeiro	Lima	Athens	Havana
Tokyo	Bombay	Leningrad	Hyderbad	Hamburg
	Istanbul	Nagoya	Liverpool	
	Karachi	Singapore	Naples	
	Madras	Melborne	Casablanca	
	Jakarta	Sydney	Colombo	
	Manila			
	Shanghai			
	Taipei			
	Hong Kong			

Table 3

The Top 10 U. S. Theme Parks 1986

Attraction	**Visitors (millions)**
DISNEY WORLD	22.4*
DISNEYLAND	12.0
SEA WORLD (FL)	4.0
UNIVERSAL STUDIOS	3.8
KNOTT'S BERRY FARM	3.5
SEA WORLD (CA)	3.1
SIX FLAGS GREAT ADVENTURE	2.9
BUSCH GARDENS, TAMPA	2.7
KINGS ISLAND, KINGS ISLAND, OH	2.8
MAGIC MOUNTAIN	2.8

*1987 estimate 26.5 million visitors!

Source: Amusement Business, Los Angeles Times, *Dec 1987*

U.S. theme parks overall enjoyed 254 million visits in 1989. Disney parks captured but 25% of the market. The cost of admission to Disney attractions has more than doubled since 1980 to $32.75 for "adults" age 10 and up, and $26.40 for kids age three to nine. Even with four-day passes ($105.60 each), standard airfare ($250 a person), a mid-size rental car ($150 per week) and a modest hotel room (one room with two double beds at $85 per night), a family of four can be expected to spend $2900 including food, souvenirs and incidentals for a typical five-night stay at peak season. This figure does not include what the family might spend on side trips to Disney's competitors.

In creating his first theme park Walt Disney concentrated on the development of the park as the key source of revenue. In the case of the Anaheim facility he realized too late that approximately two-thirds of the cash outlay by visitors is for lodging and food — and that a large segment of the discretionary spending was going to business outside the park! Having missed out capturing a significant portion of that market in southern California, in Orlando the Disney Company owns and operates its own hotels and restaurants within the park.

Using Disney World as a model for dally revenues we find that $500 a day is a reasonable 1991 "rule of thumb" as to what a family of four is willing to pay for entertainment. That level of outlay has not deterred 30 million visits to Disney World in 1989! The attraction has visitors walting in line for the opening bell. Most guests say Disney World is worth the price: "The place is spotless and we feel safer here than at other parks. I haven't met anyone who is rude." (This is true of all Disney and other quality theme parks.)

Walt Disney Co. revenues in 1989 reached $26 billion — much of it from the amusement parks. The average visit revenue is $50 per person. Disney marketeers argue that you pay more because you get more.

The marketing blitz never lets up. When you take MGM's hot new ride, "Star Tours," for example, you exit directly into the "Star Tours" gift shop. Suddenly the kids are clamoring for an $85 silver satin jacket or a $26.95 cotton sweatshirt both emblazoned with the "Star Tours" logo. Even more amazing, many of the parents are buying.

Co-location of similar competitive business has become a recognized success in the U. S. Automobile parks have so improved sales for dealers that the concept is being adopted throughout the country. Southern California theme park revenues have not suffered by the addition of other theme parks in close proximity. The ocean theme park concept should not be considered threatened if other theme parks are located in the same geographic area.

A balanced theme park should provide bountiful action from morning to late at night. A full schedule at a single location is needed to satiate the visitor's appetite for new experiences. A well-structured destination attraction eliminates the need for additional travel or location change during a vacation period. Most travelers are seeking a dream world, a fantasy-type vacation that will take them away, at least mentally, from the workaday life. Attractions that possess these attributes contribute to the creation of destination city.

A REGIONAL ECONOMIC IMPACT MODEL

Sea World of San Diego, California is a marine life and aquatic theme park that has been in existence for 25 years. Sea World in San Diego is representative of the positive impacts that an ocean theme park can have on a regional economy.

In 1989 the economic impact of Sea World was more than $611.1 million. Sea World provides full time equivalent (f.t.e.) employment for 1500 San Diegans. Its payroll was $24 million and it spent $1.2 million on capital improvements. Additionally, it purchased goods and food products for resale to park visitors. In the sale of this food and merchandise amounting to $46 million, Sea World collected $3.3 million in state sales taxes. Of this, $531,000 is returned to the City of San Diego general fund and another $398,000 is returned to San Diego County transportation funds. Sea World also pays rent to the City of San Diego of $4.1 million, and pays $1 million in property taxes. These are the elements of Sea World's business which could be called the direct economic impacts of Sea World in 1989.

SeaWorld is a major part of the draw that brings visitors to San Diego. These visitors spend a great deal of money at many businesses that do not directly or indirectly do business with Sea World, and therefore represent an economic impact that is not counted in either the above levels of economic impact. If expenditures by all out-of-county Sea World visitors were included, the total impact would be over $2.3 billion, which is 37 percent of San Diego's out-of-county visitor impacts (CIC Research Inc. 1990). 35 percent of Sea World's visitors indicated that they were in town because of Sea World. This 35 percent by out-of-county visitor's total impact is $461.1 million. Of the major impacted sectors, "Other Services" and "Hotel/Motel/Restaurants" account for over half of the business impact. The Sea World impact on skilled and unskilled worker categories amount to half of the 8,823 f.t.e. jobs.

Indirect and induced impacts are those affecting the sales linkages between San Diego's various business sectors (e.g. agriculture's sales to food processors and food processors sales to restaurants and food stores, etc.) and transactions between each business sector and San Diego households. The later includes (1) income payments to households in return for providing labor and other privately owned assets used in production, and (2) revenue from sales to local consumers. This amounts to $268.2 million. The total impact includes $73.4 million in payments to San Diego households (wages and salaries) and provides 2,854 full time equivalent jobs.

Clearly a theme park such as Sea World has significant beneficial impact on the regional economy.

THEME PARK SYNERGISM WITH OTHER BUSINESSES

Ocean theme parks can be compatible with existing maritime businesses and those providing products and services. A theme park can add a new level of positive synergism in a multiple use coastal environment There is a market for a spectrum of fantasy and real-world ocean related entertainment and educational facilities within the hotel industry. Leisure-time attractions can be an effective means to hold travelers at a given location for the duration of their stay, e.g., an ocean theme park associated with major hotel complex should be able to capture a significant share of the tourist's discretionary budget.

An ocean-oriented leisure-time attraction created as an integral part of a hotel offers the following potential:

- The hotel/park complex can be a stand-alone destination tourist attraction.
- An attraction that appeals to patrons of five star hotels.
- Additional profit generating source with a good return on investment potential.
- Provides distinction and public recognition to a hotel complex.
- Can provide an out-of-this-world ambiance for those hotel rooms outfitted with exclusive aquarium viewing windows.
- Stimulus for repeat visits
- Ocean attractions can be integrated into an existing hotel or a new hotel development.
- Attractions suitable to a particular site can be selected from a myriad of candidates.
- Advanced technologies can be incorporated into new hotel complex developments that will the improve economic feasibility of hotels in remote locations. In tropical regions, where energy costs are high, energy sources (e.g., Ocean Thermal Energy Conversion) can be considered as an alternative to conventional fuels. Using OTEC it is feasible for a hotel and park complex to effectively not only derive its electrical needs from an OTEC system, but also cold ocean water to augment room air conditioning, a bountiful supply of fresh water, and the high nutrient water for mariculture to augment hotel requirements for fresh seafood. OTEC is particularly well suited for island locations within 15 degrees of the equator and close to a deep ocean water source.

SUMMARY

Worldwide opportunities exist for strong viable businesses in large, intermediate, and small ocean theme parks. Benefits to a coastal region from an ocean-oriented theme park are:

- Economic growth
- Employment growth
- Ambiance improvement
- Change in business mix
- Expanding tax revenue base
- Enhance local education and training

- Minimal financial risk
- Permanent improvements

Benefits of coastal region ocean theme parks are clearly positive and can add significantly to the quality of life for local residents and visitors.

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Ocean Borne Waste Management Systems

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ABSTRACT

For several decades marine-based waste management systems were synonymous with dumping raw, untreated waste into the ocean. Municipal solid waste (MSW) washing ashore and causing beach closures, along with reports of threats to marine life near sludge dumping sites has created a hostile public perception regarding any marine-related waste management activity. Despite this, a growing coastal population, combined with the depletion of waste management options in those areas, provides an opportunity for new systems of waste management. Waste market trends clearly present an opening for innovative systems that may utilize existing port facilities, and provide a comprehensive waste management solution for congested coastal communities. This paper describes three types of marine-based waste management systems, and cites past uses as well as the limiting factors which have impaired continuation of their utilization. We discuss the proposed FlexEs 2020 system™ and the way FlexEs proposes to approach the municipal solid waste (MSW) market with a marine-based system. In order for the system to be viable, we need to obtain permits from the U.S. Environmental Protection Agency (EPA) and other federal agencies. While MSW incineration is clearly exempt from the ban on ocean dumping and incineration at sea, substantial groundwork with the EPA needs to be undertaken by any company proposing an MSW incineration system. This paper calls for the re-examination of a wide array of issues concerning ocean dumping of processed materials, the reevaluation of categorizing incineration as dumping, and calls for the relevant

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regulatory agencies to support efforts to include a marine-based waste management system as a part of the solution to the waste disposal problem.

BACKGROUND

The history of marine-based waste management systems is not a long one, though its reputation is less than stellar in its mere thirty years of existence. A few examples follow which typify its sour history.

In the mid 1950s there were several boating contractors who hauled thousands of sealed drums containing extremely toxic materials, including nuclear waste, and dumped them twenty miles off the Boston Harbor outlet. Their clients were highly reputable organizations such as the Massachusetts Institute of Technology, Harvard University, and General Dynamics. None of those involved thought about the possibility of drifting drums, corrosion of the drums and spillage of its contents into the environment, which has since resulted. The U.S. Environmental Protection Agency considered capping the area, but due to the extremely high cost involved, the plans have been put on hold. This is one of many examples of dumping at sea, which is now illegal.

In the early 1980s there were test burns of liquid hazardous waste at sea in the Gulf of Mexico, with no pollution control equipment. This program met with enormous public opposition and was suspended by the EPA. One of these ships then went on to burn hazardous waste in the North Sea, but was ultimately retired in 1989.

There is also the famous story of the MOBRO; a garbage-filled barge which originated from Long Island and traveled for weeks without finding a disposal site for its trash.

This backdrop obviously creates an uphill battle for any company that sets marine-based waste management as its operational goal. The examples of marine-based waste management operations are not ones we want to emulate. The public perception of waste management at sea is the single-largest obstacle we will need to overcome.

Population Concentration and Generation Trends

Population projections show that by the year 2000, more than two-thirds of the U.S. population will be concentrated within 50 miles of the shore. Similar demographic trends are occurring world-wide. Naturally, the amount of municipal solid waste (MSW) and sewage that is generated follows the same geographical distribution. Furthermore, as a rough cross section of suburban growth within 50 miles of shore shows, affluent communities generate more waste per capita than communities inland.

Most industrial waste is concentrated in a similar manner to the solid and sewage wastes. Moreover, a large number of petrochemical and chemical industries rely heavily on marine transportation for their raw materials, and are typically found adjacent to seaports. These facilities are major generators of liquid hazardous wastes.

Waste Management Methods

The five basic methods of waste management are:

- Reduction: elimination of waste intensive products at the source;
- Recycling: reusing part of the waste stream for new products;
- Composting: natural decomposition of organic wastes;
- Incineration: high temperature controlled burning for significant volume reduction. Requires site (typically landfill) for ash residue;
- Landfilling: burying waste materials.

It is becoming increasingly clear that no single technology can solve the entire waste problem, and that a combination of the above methods is required for a comprehensive solution to our growing waste problems.

Land Depletion and Siting Difficulties

Landfilling has been the predominant method of disposal for all types of waste, but the precautions and regulations associated with preventing hazardous materials from entering the ecosystem impose very stringent restrictions on landfilling. The siting of new landfills for MSW and sewage sludge is also growing increasingly difficult.

Siting of new landfills and/or processing facilities, particularly waste incineration facilities, in metropolitan communities is becoming close to impossible. Urban build-up along the ocean shores has depleted the amount of urban area available to site a large landfill. Older landfill facilities have closed down when they reached capacity, and replacement capacity is unavailable due to the cost of land, and local opposition from neighboring communities. The Not In My Back Yard (NIMBY) syndrome has doomed most attempts to create local new waste processing and disposal capacity.

Shore communities and industry have looked to remote sites, further inland, to take their waste. Transportation systems have been set up in the last several years, especially in the northeastern United States, but also in other locations worldwide, to move waste by truck and rail to inland facilities. Residents of the recipient states are becoming increasingly mobilized against the importation of waste from other states and Congress has considered legislation which would allow states to ban the import of waste. Such communities argue that they should not bear the environmental impact and health consequences of distant cities' waste.

The argument put forth in this paper is that (1) there is a need for additional waste disposal capacity, particularly in coastal cities; (2) the land-based options of local landfilling, long distance landfilling, and incineration have formidable problems associated with them; and (3) used appropriately, applying current waste management principals in a marine-based system is a viable component of a comprehensive waste management solution.

WASTE MARKET SEGMENTATION

The waste market, for purposes of identifying a market niche for marine-based waste management, includes three major waste types: municipal and industrial solid wastes, hazardous wastes, and sewage wastes. This paper focuses on those wastes which lend themselves to processing by technologies that can be accommodated in a cost competitive manner within a marine environment.

Segmentation By Waste

The major elements effecting waste management in the marine environment, and thus define the types of waste that fall under the category of marine treatable wastes, are:

- Generation Sources
- Waste Material Consistency
- Toxicity and Hazard
- Collection Method
- Processing Methods
- Residual Material Volume
- Residual Material Consistency and Toxicity

Our analysis focuses on waste materials that are generated within a short distance from a port facility, or can be brought to the port via an inland waterway marine transportation. There is a clear preference for the lowest toxicity material, and a need to extract all additional toxins from it at a port material treatment facility. After maximum source reduction and recycling, under its broadest definition, have been attained, there will still be a need to process the residual waste flow and FlexES is focusing primarily on ocean incineration on-board a ship.

Geographic Segmentation

Geographic segmentation of the market will determine what portion of those waste products that fall under the applicable category will be accessible to marine solutions.

Accessibility to deep ocean ports, transportation routes and alternative waste management services will define the geographic market. Alternatives and transportation routes belong in this category, since only when land-based solutions are depleted and new ones not available does the price become competitive enough to support a complicated and capital intensive marine-based system.

MARINE BASED WASTE MANAGEMENT SYSTEMS

Proposed Definition

A marine-based waste management system is a ship, barge or ocean platform-mounted waste processing and disposal system that would be permittable on land.

More broadly, an acceptable marine-based waste management system is an implementation of land-based waste processing systems onboard a vessel for the purpose of processing waste in a marine environment.

The definition begs the question: "Why bother to put such a system at sea?" The answer lies with the siting and marine transportation advantages it provides.

Implicit in this definition of "acceptable" marine-based waste management is that the same environmental control apparatus that is required on land should also be included in a marine-based system. There is legitimate scientific debate about whether there is a need for comprehensive and expensive environmental control equipment in a marine environment. Computerized dispersement models and theoretical analysis of the ocean surface surrounding several proposed hazardous waste incineration sites showed a barely measurable effect on the environment and the ecosystem. Physical monitoring of the Gulf of Mexico test burns, which had no environmental control equipment, found readings in the parts per billion.

The answer, ultimately, is not just scientifically determined, but must consider the public sensitivities of engaging in waste processing at sea — away from public scrutiny. The hazardous waste incineration program in the Gulf was suspended by the EPA, largely because of the extraordinary amount of public opposition it encountered. The single-largest public meeting ever held by the EPA was in Brownsville, Texas and the subject was designation of the offshore site for the incineration of hazardous waste and the permitting of Chemical Waste Management Inc. incinerator ships.

From a business perspective, it is prudent to assume that the only way a marine-based waste processing system will be allowed to become operational is if it complies with shore-based regulations. Experiences of the last decade of ocean incineration suggest that such systems should expect intense public scrutiny. Business should anticipate the public's assumptions of bad intentions on the operator's behalf, and fear of "out-of-sight equals out-of-mind" operating practices. Compliance with shore-based regulations, as expensive as they appear to be on the surface, may be the key to initiate trust building between the marine waste management industry and the public.

The 1972 London Dumping Convention, and subsequently the 1988 U.S. Ocean Dumping Ban Act and the amendment to the Marine Protection, Research and Sanctuaries Act (MPRSA), prohibit dumping of sewage sludge and industrial waste at sea. Subject to these laws and the proposed definition, a number of existing and proposed marine waste management systems may not fall under an acceptable systems category.

Ocean Dumping

Ocean dumping was, and probably still is, the most common use of the sea as a waste management site. Ocean dumping is generally limited to materials that are easy to load on hopper barges, or easily dumped directly into the ocean via pipeline. Thus, sewage sludge is the most common form of waste material dumped at sea. For several decades New York City dumped its dewatered sludge in two different sites off the Long Island coast. This practice is banned under the 1988 amendment to the MPRSA, and will stop on December 31, 1991.

Loading barges with untreated sewage sludge for the purpose of open dumping, even in a designated site, will not fall under our category of a viable marine based waste management system since it will likely fail the acceptability test if handled similarly on land.

Another waste management method, recently used off the shore of New Jersey, is the practice of open burning of wood pilings onboard open barges at sea. The burning barges are at times visible from land, they are not covered and do not employ environmental control apparatus. This rudimentary method of disposal is operating under a U.S. EPA temporary permit, and is slated for cancellation in the near future. Burning wood pilings offshore has mobilized New Jersey shore communities in opposition to ocean incineration, and created another barrier to employ the ocean for implementation of a well designed and constructed waste management system.

The aforementioned ocean dumping history, including such operations as the one discussed in the background section of this paper, have created a negative public perception of ocean waste management activities. Any company that chooses to implement an offshore waste management system will have to deal with this potential public opposition.

However, there may be cases of dumping processed material in the ocean, in a fashion that will prevent the dumped material from escaping into the ecosystem under any worst case scenario (e.g. encapsulation or vitrification of slightly hazardous materials), that will pass the acceptable marine waste management definition test. There may be, in fact, constructive uses for processed material controlled dumping. Examples include breakwaters in deep sea ports, artificial fish spawning reefs, and artificial islands or landfill extensions.

We may learn of other constructive uses for treated waste in the marine environment, and the business and scientific community must work to promote those which are sensible, cost effective and environmentally sound solutions to a serious problem.

There is an open debate within the scientific and business community about proposed deep ocean dumping of untreated or partially treated sewage sludge directly onto the deep ocean floor. Methods being investigated include the use of a huge hose from a surface vessel to an area close to the ocean floor, the use of capsules released from a ship with a sinker to descend at 50 miles per hour and bury itself in the bottom ooze, or the use of huge plastic balls containing the sludge to be lowered in a controlled manner to the ocean floor.

The definition of acceptable marine waste management system, as presented in this paper, may not apply in the case of deep ocean dumping. Nevertheless, we await further research on this matter before one concludes whether this is a viable marine-based waste management system.

Permanent Ocean-Based Processing

We define permanent ocean-based processing as a permanently positioned marine platform, either floating or attached to the ocean floor, but fully detached from land, that processes wastes shuttled to it from shore. If the waste management system generates power, a permanent ocean-based process is limited in the distance away from shore that it may operate. Otherwise, such a system may operate in any offshore location, and does not need to be anchored or permanently attached, but may be dynamically positioned in a given site. We are unaware of such an operating system; however, it holds a great deal of promise as a method of ocean-borne waste processing. A permanent offshore processing base may prove to be the optimum use of an advanced and inexpensive marine-based transportation system for collection of wastes at various shore locations, transportation of that waste to a single site and distribution of by-products and waste residue on the return trip of such vessels. We appreciate the need to resolve numerous technical and regulatory issues before such a system may be contemplated for implementation. Such a system will also require a major change in the waste handling infrastructure.

A permanent offshore MSW and sludge co-incineration plant was proposed to the City of Boston in 1986 by Wheelabrator Environmental Systems, Inc. and McDermott Inc. The companies promoted this plant, which was to be positioned sixteen miles out in the Massachusetts Bay, as an alternative to the highly controversial plan to build an incineration plant in the South Bay, a heavily populated area in the south part of Boston. The "South Bay" plant was to have been built by a competitor who has since moved its proposed plant to a location some 60 miles away. The Wheelabrator-McDermott plant was to co-incinerate MSW and sewage sludge and produce energy that was to be brought to shore via an underwater cable. Although the plan was well received by some public officials, it was not further promoted due to a variety of business considerations. Some technological issues had to be overcome, but in reviewing the basic proposal, it does not appear as though there would have been major engineering or construction hurdles.

A major advantage to the permanently positioned marine-based waste management system is the ability to recover energy from the incineration process, using existing technology. This is a positive environmental attribute, primarily because it displaces conventional energy sources.

A key technical and regulatory issue associated with a permanent ocean-based waste processing system is the need to transfer waste from one vessel to another at sea. Such an operation is difficult in open waters: it creates a system that is weather dependent at a critical point in the operation, and while the risks of spillage at sea may be minimized, they cannot be eliminated. Even though highly reliable engineering designs and operational procedures may be developed, there is a U.S. Coast Guard ban on transfer of wastes between vessels at sea, and there may be other regulatory issues with which the system may have to contend.

Combined Transportation and Processing Systems

The first large scale marine waste management system was introduced in the late 1970s in the form of a converted chemical tanker that was fitted with a rotary cup type incinerator. The intention was to collect liquid organics at designated ports, and sail to a designated ocean site where the material would be incinerated. The basic system includes pier-side loading of the vessel, which is equipped with sufficient hold space for the waste load to be processed, and carries on board a complete processing facility, in this case, a hazardous waste incinerator.

The U.S. EPA led the effort to pursue a marine solution as an alternative to land-based hazardous waste incinerators. The premise was that the ocean will act as a natural neutralizer, thus marine based hazardous waste incineration systems would not require scrubbers or other air pollution control equipment. This provided a way to construct a waste management system that would be relatively inexpensive to operate, and supposedly would not need to contend with the NIMBY phenomenon.

In the early 1980s several companies entered the field of marine hazardous waste incineration. Pioneering the effort was Chemical Waste Management, Inc. of Oak Brook, Illinois, a subsidiary of Waste Management, Inc. the largest waste management company in the world. Chem-Waste had three ships, of which only one was a new construction vessel. In 1983, At Sea Incineration, Inc. received a U.S. Maritime Administration Title XI loan guarantee to build two new hazardous waste incineration ships at Tacoma Boat, in Washington state. When the EPA abandoned its offshore incineration program two years later, the company declared bankruptcy, dragging down with it the Tacoma shipyard. Of a total of five liquid hazardous waste incineration ships constructed or converted, only one — the VOLCANUS II — operated commercially for a significant period of time.

Despite millions of dollars invested in the five vessels and millions more invested in engineering, infrastructure, licensing, permitting and other activities, we believe that the basic premise in the design of those hazardous waste management incineration ships was flawed Equipped with no environmental control apparatus, those systems did not comply with the proposed definition of an acceptable marine waste management system. This type of technology would not be permittable on land. Such hazardous waste incineration ships may have fallen under the "acceptable system" category had their engineering and construction been designed to meet equivalent land-based environmental controls. We also believe that the massive opposition to such systems, had they been properly designed, would have been significantly lower in volume and intensity, and that the field would have been open to more developments in other waste areas if not for this initial venture into marine-based waste management.

MSW is the one of few waste products that are not banned by the Ocean Dumping Ban Act, and provides a viable market for a marine based waste management system. Flexible Environmental Systems, Inc., (FlexEs) was founded to develop, design, construct, and operate an environmentally sound marine-based waste disposal system. This FlexES 2020 System™ is based on innovative engineering utilizing field-proven waste processing technologies. FlexES has a patent pending for the FlexES 2020 System.

The FlexES 2020 System consists of a seaport recycling facility, where the entire waste stream is sorted and recyclable materials are reclaimed, and of a ship-borne incineration plant, where the non-recyclable material is incinerated. The system is designed to handle future changes in waste stream volume and mix.

The FlexES 2020 System consists of the following components:

Marine Transfer Station

Unloading of municipal collection trucks at a port facility for a tipping fee: Waste and recyclables are either directly unloaded into the recycling facility or into barges for transportation to the recycling plant.

Recycling Facility

Highly mechanized combined with supplementary manual sorting and processing of all waste and recyclables: Recyclables are prepared as raw materials for re-use and household hazardous wastes are containerized for proper disposal at an independent facility. Materials removed from the waste stream include aluminum, steel, glass, plastic, cardboard, and household hazardous materials

Incineration at Sea

Residual (non-recyclable) MSW is loaded onto a newly constructed incineration ship. Incineration will take place at an EPA designated site, using current best available air quality control technology. The incinerator ship is equipped with four traveling stoker grate refuse-derived fuel incinerators, very similar to stoker grates that were used to power coal-fired ships in the middle of this century. Waste will be mechanically moved from two MSW holds and fed into the incinerators. All four incinerators will operate continuously while the ship is in the designated incineration site. Flue gases will be scrubbed in an acid-gas scrubber, and cleaned in a series of bag houses prior to exiting to the atmosphere. The FlexES incineration ship is designed to adhere to all land-based air quality requirements of a MSW incineration plant. The incineration ship is compatible with any FlexES recycling facility. A single incineration ship may serve more than one recycling center.

Incinerator ash will be brought back to shore. At this stage, the plan calls for ash landfilling, however, FlexES is developing a thermal-based proprietary ash encapsulating process, becoming a basis for reusable products. We are also carefully monitoring developments in this area of a number of industrial and academic research projects.

"FlexES 2020 System" Adaptability to Market Change

The recycling facilities' internal design allows for the addition of separation lines for the processing of source-separated recyclable (curb-side collected recyclables).

An incineration ship is the only known way to share incineration facilities between remote cities or among several systems without locking a single community into producing a minimum amount of trash to support the system. Thus, the FlexES 2020 System is less sensitive than land-based — energy producing — incinerators to reductions in tonnage as cities implement source reduction and recycling programs.

"FlexES 2020 System" Environmental Attributes

The FlexES 2020 System was designed with a high degree of environmental sensitivity, addressing the following issues:

- Source Reduction and Recycling:
  - -Highest achievable recycling by mechanizing the process;
  - -Complementary MSW and source-separated recycling system;
  - -A strong financial incentive to maximize recycling and minimize the amount of incineration performed.
- Household hazardous wastes (HHW):
  - -Removal of HHW prior to incineration;
  - -Containerization and proper disposal.
- Waste Handling:
  - -No open waste transfer at any stage of the process;
  - -Ocean dumping of MSW is physically impossible;
  - -Safe, compartmentalized new construction ship;
  - -Best available air quality protection equipment used with "black box" operation safeguards on air quality control apparatus.

Our legal research suggests that such a system would fall under the Jones Act, and will require such vessels to be U.S. constructed, flagged and operated.

ATTRIBUTES OF MARINE BASED SYSTEMS

Marine Solution Major Advantages

Ship, barge or offshore platform-based waste processing plants offer significant advantages in certain circumstances. The most important factors in determining their viability are the comparative economics and the ease or difficulty of siting waste processing facilities on land.

Marine-based waste processing should be limited to such technologies that do not require discharge of untreated materials into any other secondary treatment facilities, or alternatively, that can demonstrate that all such discharge is done on shore only. Design of marine based waste management facilities should include all best available environmental control apparatus, and sufficient monitoring to assure the system complies with all landbased facility requirements.

When proposing a marine based waste management system, it must be economically sound and in full compliance with all rules and regulations. Such a system will typically offer the following major advantages to the service seeker:

Ease of access

Most major urban centers have more pier space than is currently utilized. Trade developments in the last several decades have left ample unused shorefront industrial space. This space is typically in central locations and is usually easily accessible by rail or truck.

Distribution of by-products

If the marine based process involves any distribution of byproducts for further processing or final disposal, a marine-based transportation system is most likely to be the least expensive method of transportation. This is an extremely important element, since transportation accounts for a major portion of the cost for most such by-products.

Flexibility of service

A marine-based plant is movable by definition, and thus may serve different communities when market changes occur. A facility of this type may be shared between remote locations, a unique quality of marine processing facilities.

Minimization of local impact

Any industrial facility will have some amount of impact to the surrounding community. Processing at sea eliminates any potential local adverse impacts, leaving only the impacts associated with the transfer facility located in or near populated areas.

Economic Advantage

Construction of a complex and large scale waste processing facility requires major infrastructure support such as large equipment-moving cranes, roads for transporting heavy equipment, welding machinery, and power generation. Construction infrastructure already exists in shipyards which are designed for large scale construction projects. Building, land, land improvements and other system infrastructure exist by default if the system is ship mounted. The net result is economies in construction cost that can offset the more complicated operation method required in the marine environment.

Potential Drawbacks

Marine-based waste management also has its disadvantages. They are primarily related to the additional transportation required, the increased number of waste handling steps, and the potential hazards of operating at sea.

Energy use

Energy is consumed to transport waste to sea, whether it be a platform-based or ship-based operation. Unless energy is produced, it is also needed to operate the incineration plant and the waste handling systems on-board the processing vessel. Land based systems that do recover energy use a portion of the energy generated to power the operation.

More waste handling steps

By necessity, there are more waste handling steps because of the transfer of materials from land to sea-going vessels and the transfer back again of any residual materials from the process. Additional handling results in higher operating costs and increases the chance of accidents.

Non-continuous ship-borne plant

In the case of a ship-borne waste management system, the processing cannot be a continuous operation. Every time the ship leaves the designated incineration site in order to come into port for loading of additional product, waste processing must be suspended.

Potential spillage risk

In the event of a spill, it would not be possible to contain liquid hazardous wastes and they would be dispersed into the ocean with negative effects on marine life.

IMPEDIMENTS TO MARINE SYSTEM IMPLEMENTATION

Technological Barriers

There is little experience with engineering solutions for marine-based waste management systems other than installing rotary cup liquid hazardous waste incinerators on board chemical tankers, and moving the liquids to it via pipe. Some of the engineering challenges ahead are:

- Sludge/municipal solid waste co-processing;
- Long distance underwater power cables connecting to floating platforms;
- Solid waste handling and transfer between two vessels at sea;
- Ash handling in a marine environment;
- Maintenance of a short-cycle system at sea;
- Compact design of waste processing systems for a space-constrained environment.

Public Perception Issues

The major obstacle in implementing an environmentally sound and economically advantageous marine-based system is overcoming the public perception of "out-of-sight equals out-of-mind." The public, with good historical reason, is distrustful of industrial activities which operate away from the public eye. It will be critical to work in partnership with environmental groups and local community organizations to creatively design a system such that many of these concerns can be overcome. In addition, satellite communication systems can be employed real-time to relay operating information, emission monitoring, and other relevant data for public review.

In addition, some environmental groups are known to oppose MSW incineration generally, and others specifically oppose use of the oceans for any waste processing purpose because of concerns about possible effects on marine life, the likelihood of accidents and other issues. Some of these constituencies may be difficult to sway, but it is our responsibility to find solutions for any reasonable concerns they may raise.

Regulatory Limitations

The 1972 London Dumping Convention bans industrial waste processing at sea, and defines hazardous and any industrial waste incineration as "dumping." This wholesale ban on all marine dumping of any materials, and the definition of incineration irrespective of the method used, is a major impediment in the development of marine-based systems. While municipal solid waste is not banned, additional work is required by U.S. regulatory agencies to enable further development and implementation of economically and environmentally sound marine-based waste processing systems.

REGULATIONS, PERMITTING AND FACILITY SITING

Waste disposal is subject to heavy government regulation and any marine-based waste management system will be required to comply with a myriad of complex laws and regulations at all levels of government. The following is not intended as a full description of all applicable laws, but rather is a selected and brief summary of the regulatory requirements of MSW incineration at sea.

A system will require federal, state, and city permits, although some of the federal permitting activities required for a pioneering system may not have to be repeated for subsequent operations.

EPA Incineration Permit

The key federal permit is an EPA permit for a floating incineration plant. The EPA issues ocean incineration permits under the 1972 Marine Protection, Research, and Sanctuaries Act, following a two-part process — site designation and facility permitting.

The EPA needs to designate an offshore incineration site. In 1982, the EPA proposed designation of the North Atlantic Incineration Site, an area approximately 130 miles off the eastern seaboard, for incineration of hazardous waste. While this site was ultimately not designated because incineration of hazardous waste at sea was banned by Congress, the EPA completed an Environmental Impact Statement (EIS) on the site, evaluating the potential environmental impacts from incineration. Another site, located in the Gulf of Mexico, that was designated for offshore hazardous waste incineration was formally de-designated on February 27, 1991.

EPA suggests that a company applying for offshore incineration permit may update the original EIS and submit it for public comment as the first step in the site designation process. The second part of the EPA permit process will involve permitting the actual floating incineration plant.While the incineration site only has to be designated once, permits must be issued for each new facility.

Other EPA Requirements

The marine-based waste management system will also have to comply with new regulations proposed by the EPA under the Clean Air Act for new municipal waste combustors. These provisions require the use of "Best Demonstrated Technology," which is what FlexES proposes, and the regulations will set new specific emission limits for a variety of pollutants.

Each system will also need a Coastal Zone Management (CZM) Certification from the EPA. The CZM certification may be issued in conjunction with the state where the port facility is located. The marine-based waste management system will be reviewed for its consistency with state CZM programs, which are designed to protect coastal areas from project impacts.

Other Federal Permits and Regulations

Other federal permits required for a marine-based waste management system include those from the Department of Transportation (U.S. Coast Guard) for transport of the vessel in coastal waters, and possible permits from the U.S. Army Corps of Engineers for construction or alteration of pier facilities. The ocean-going vessels must also comply with all American Bureau of Shipping (ABS) standards. The marine-based waste management system operation will also have to comply with Occupational Safety and Health Administration (OSHA) standards which regulate the workplace.

State and City Permits

For any marine based waste management system, there will be a variety of state and city permits to obtain which focus almost entirely on the port facility. Typically, state regulations set the framework for city-imposed regulations, although local jurisdictions may have a few more specific requirements.

State environmental agencies require that an EIS be conducted for activities related to the port facility. It is likely that a single EIS pertaining to all aspects of the system will be reviewed by federal, state and city agencies. The EIS will require a public review process.

To permit a marine-based waste management system, most states will require that the system be consistent with state and, if appropriate, local waste master plans. Many states and cities now have plans which contain ambitious waste reduction and recycling goals which must be attained prior to permitting an incineration system.

Port Facility Siting Issues

One of the first issues to resolve in the permit process is the location of the port facility. Several of the criteria that will be used to determine if a site is appropriate for consideration are:

- Appropriate Zoning/Location in Manufacturing Zone (M3)
- Water depth
- Pier length
- Buffered from populated areas
- Rail access
- Truck access

Siting facilities, no matter where they are proposed, invariably raises controversy, even when they are clearly for the public good. Only the most benign facilities escape public scrutiny. Siting of a port facility will be no exception. Siting has increasingly become an issue for communities surrounding proposed sites and those en route to facilities.

The following represent typical community siting concerns:

- Truck traffic
- Noise
- Odor and air pollution
- Waste spillage
- Rodents and pests
- Reduced real estate value
- Elimination of free access to waterfront property

These concerns should be carefully addressed by any plan for a marine-based waste management operation.

CALL FOR JOINT ACTION

The need for innovative, sensibly engineered and environmentally sound waste management systems is clear. We believe the market is ripe for systems that will contribute to solving our waste disposal problems After all the reduction at the source and the recycling at the household and plant level are achieved, there will still be a need for disposing of the residue We hope to have shown that there are significant advantages of using a marine-based waste management system. However, in order to have a marine-based waste management system play a serious role in today's waste management industry, there is a clear need for joint action on behalf of all involved: the marine industry, academia and research centers, federal and local government, and participants of this conference.

Marine Industry

The marine construction industry, primarily shipyards, have vast resources of heavy industry infrastructure in most industrialized nations. Due to international trade trends, and the movement of most ship and platform building to Southeast Asia, most such facilities are underutilized. Use of idle shipbuilding facilities for construction of waste management systems may revitalize them and show their competitiveness with traditional land-based systems.

Academia and Research Centers

We urge industry, government and research institutions to further study waste residue vitrification methods and their effect on the marine environment. The key issue to be studied, documented and publicized is the leachability, or lack thereof, of various encapsulation and vitrification methods. We suggest that if findings of such studies show no negative, or preferably some positive effect on the ecosystem including marine life, it may be developed as a sensible alternative to landfilling.

Further research of constructive marine use of waste by products may include studying of artificial reefs, breakwaters, dams and barriers or artificial islands.

Federal Government

The U.S. Environmental Protection Agency has no budget for its ocean incineration program and has in fact deactivated the offshore incineration program. We urge Congress and EPA to reactivate the program, and take a different look at an offshore incineration program as a possible component within the waste management hierarchy.

We urge the EPA to reopen the discussion regarding the definition of dumping. Reevaluation of the ban on dumping should be carried out subject to aforementioned solidification and vitrification studies. If there are constructive uses for waste materials as mentioned, such waste management options should not be banned in advance.

Another definition issue to be resolved is whether incineration with environmental control apparatus is considered dumping. Under current rules, this question has not been completely addressed. We feel that addressing this question will broaden waste management options for municipalities, industry and the waste management community. We submit that incineration with environmental control apparatus, complying with the Clean Air Act, should not be considered dumping. We call on EPA to reconsider such definitions and address this issue as soon as possible.

Local Decision Makers

We call on local decision makers to become aware of the marine solid waste management option, and to consider the marine solution as an alternative waste management option at their disposal. We hope that with further research and with early acceptable marine waste management systems in place, decision makers in coastal communities will consider the marine system as a real alternative to current solutions.

This Conference

We urge conference participants to call on all the above to revive plans and support funding for research, development, legal and regulatory work to promote the marine environment as a viable and safe medium for waste processing and disposal. We call on this conference to urge the London Dumping Convention, the U.S. Congress and the U.S. Environmental Protection Agency, to reevaluate the wholesale ban on any industrial marine based waste management activities subject to further studies of specific issues raised in this paper and during other sessions in this conference.

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Coastal Ocean Space Utilization: Threshold of an Evolving Global Ocean Space Utilization Program

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ABSTRACT

"Coastal Ocean Space Utilization (COSU)" may be viewed as a pioneering effort, initially confined with respect to ocean space, and yet preparatory to an integrated implementation of an evolving "Global Ocean Space Utilization" program. Moreover, for both COSU and global development, a need exists for a unique kind of new ocean technology which is discussed below. This new technology is, in short, founded upon (i) an unelaborated concept of a single seaborne platform configuration possessing certain unique attributes, and (ii) an elaboration of a unique kind of "maritime settlement" precisely defined below.

As for how the introduction and implementation of these concepts might either pace or be paced by a concurrently evolving global COSU program, at least one thing is certain: every action taken to implement the concepts now would be effective, taken not just in response to global environmental change, but also with the certainty that such an action would have favorable global economic effects.

PREFACE: ON RENEWING OUR "ABILITY TO ATTRACT THE LIGHTNING OF ECONOMIC REVOLUTIONS"

In December 1988, an article appeared entitled *Bush Gropes for a New Grand Strategy.*[1] This article was destined to be little more than some sort of improvisation intended to extricate the United States from a very serious and at the time apparently unresolvable, but now much less threatening, predicament. That predicament was one which had caused the leaders of our government gradually to

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conclude that (in the words of Bush's national-security adviser Brent Scowcroft) "we have failed to develop a strategic concept for dealing with the Soviet Union."

In December 1988, however, that predicament — even if apparently much less threatening now — could in fact have been successfully addressed through a presidentially encouraged implementation of the science and technology advice that had by then already been superbly presented in a review essay by The Rockefeller University's Executive Vice President, Rodney W. Nichols.[2]

"This essay," wrote Nichols in *Technology in Society*,[2] "is both a review of an earlier volume [3] (hereafter abbreviated *S&T Advice*) and an independent assessment of the book's several themes, *S&T Advice* is sprawling...scanning most perspectives on a diverse subject. Three quarters of the papers concern advice to the president. The remainder deal with issues facing Congress and the judiciary. What are the basic themes of the book? A diffuse theme is 'science policy.'...Another theme is 'technology policy,' *which barely exists today*" (emphasis added).

To anyone seriously concerned with the basic theme of the present paper, this would surely convey a note of caution, warning of certain potentially adverse consequences. Indeed, Nichols's very next sentence became quite explicit about the nature of such consequences, when he went on to write: "Improved technology policies are *crucial* for the nation's economic future; *ignoring this* may be hazardous for the nation's prosperity"[2] (emphasis added).

In fact, may it not be true that the deepening economic troubles experienced by Americans today are themselves a particular consequence of the circumstance that, insofar as "economic security policy" is concerned, there is no element of "technology policy" relevant thereto that even "exists today"? And may it not furthermore also be true that the potentially incurable adversity will inevitably become a totally incurable adversity — if no presidentially encouraged, broad and timely American action occurs in response to Nichols's constructive advice and his restrained yet nonetheless cogent warning against "ignoring this" advice?

Especially in this latter light, therefore, an adequate understanding of the causal relationships underlying this warning by Nichols might best be sought through thoughtful consideration of the following statement by William A. Blanpied, taken from *S&T Advice*:

> ...it is useful to recall the intention of the Congress in creating the existing science advisory system. The National Science and Technology Policy, Organization, and Priorities Act of 1976 tried to do considerably more than simply establish OSTP (the Office of Science and Technology Policy) and designate its director as the President's Science Advisor. It also assigned to OSTP a number of specific coordination, evaluation, analysis and planning functions designed to provide its director with the in-depth knowledge about the entire federal science and technology system and the impact of its activities on the nation as a whole that would be required of an effective Science Advisor. More important, the Act attempted to articulate the elements of a broad *science and technology policy* in terms of

> *specific national goals and needs*, with the clear implication that the Science Advisor had the *responsibility to provide advice (to the president)* in the context of a coherent *science and technology policy* (emphasis added).[2]

In short, unless and until all of the foregoing conditions are met, essentially as they were originally mandated by Congress in 1976, the opportunity may simply never arise for the science and technology advice set forth by Nichols in his essay to lead successfully to a means of curing the "apparently unresolvable...predicament" and "accompanying host of...profound and potentially incurable adversities," all of which still continue to weigh heavily upon American society.

President Bush had not yet learned the true meaning of the equally pertinent message conveyed in the following abridged version of the text of Nichols's essay: "It is *economic* trends that call for action, and the *economically* big-time technology is what the president and the Congress want to talk about... What exactly is the technical community, symbolized by the president's science and technology adviser, to do about this economic crunch? Surely it is not enough to stick to our R&D knitting... Although we don't know quite what to measure in the "fundamentals" of technology and economic growth, we do know, in Rosenberg's and Birdzell's (historically prescient) words, that:

> the underlying source of the West's *ability to attract the lightning of economic revolutions* was a unique use of *experiment in technology and organization to harness resources* to the satisfaction of *human wants*. The key elements of the system were the wide diffusion of the authority and resources necessary to experiment; an absence of more than rudimentary political and religious *restrictions* on experiment; and *incentives* which combined ample rewards for success, defined as the wide-spread *economic* use of the results of experiment, with a risk of *severe penalties for failing to experiment*" (emphasis added).[4]

As for "renewing America's ability to attract the lightning of economic revolutions," perhaps the most important requirement of all is that which Nichols has singled out in his essay:

> The White House's Office of Science and Technology Policy should be at once a resource, a clearinghouse, and a symbol. As an intellectual resource, it needs larger staff and discretionary funds to fulfill the goals for *integrating all of our R&D assets into an effective national and international strategy for the 21st century*... It is by no means clear that the science adviser needs the symbol of cabinet rank to be effective. But it is abundantly clear that *the necessarily broad and deep science (and technology) advice (to the president)* cannot be provided on the cheap or from a distance (emphasis added).[2]

SHOULD WE TRY "TO ATTRACT THE LIGHTNING OF ECONOMIC REVOLUTIONS" BY LAND, BY SEA, OR BY AIR PLUS OUTER SPACE?

In March 1984, *Time* magazine published a cover story[5] entitled "That Monster Deficit," which concluded that "closing the budget gap is not an economic or technical problem. It is a political problem." Under a more penetrating analysis, however, it actually turns out that the problem of "closing the budget gap" — which obviously has become much more difficult to resolve — could still be promptly depoliticized, simply by treating it alternatively in terms of "the 'fundamentals' of technology and economic growth," an as yet little developed interdisciplinary field of study whose economic significance has been noted by Nichols.[2]

Clearly, this alternative treatment must commence with a recognition — along the lines so well expressed in the preceding quotation from Rosenberg and Birdzell[4] — of certain hitherto poorly discerned opportunities for acquiring new national wealth on a very large scale. There are, of course, many historic examples of relatively sudden "quantum jumps" in the wealth of nations, resulting largely from worldwide exploitation of the vast untapped economic resources of the earth's land masses. But in the recent past, during which the rapid depletion and deterioration of such terrestrial economic resources has had to be seen as the chief underlying cause of current worldwide economic distress, and during which, ironically, outer space has become generally perceived as the most promising "new frontier now open to commercial and industrial — and military — exploitation," it is still obviously impossible to envisage any *practical* solution to the current budget gap problem in terms of acquiring new national wealth on a very large scale via that outer space option.

On the other hand, American decision makers have tended to ignore the fact that the world ocean provides an unquestionably practical alternative suited to the specific objective of solving the budget gap problem. It further offers the unique "new frontier" which most urgently requires the immediate involvement of American private commerce and industry and the federal government, respectively, through joint ventures capable of yielding abundant economic returns and concomitant military benefits — in both instances on a global scale, but nonetheless *subject to strict environmental constraints*.

Given America's immediate need for such practical joint action by both private and public sectors, it should be especially clear that for the Bush administration to defer pursuing — or, worse still, to ignore — the option of thus restrainedly exploiting the world ocean would certainly be to invite an economically and even militarily disastrous outcome from which this country might never recover.

AND WHAT IS THE FIRST "KEY ELEMENT OF THE SYSTEM" NEEDED "TO ATTRACT THE LIGHTNING OF ECONOMIC REVOLUTIONS"?

In this connection, let us return to the quotation from Rosenberg and Birdzell[4] — this time, in the particular context of trying *"to attract the lightning of economic revolutions"* through a unique use of *experiment* (at sea) in (innovative ocean engineering) technology and organizaton to harness resources (i.e., ocean assets and new R&D assets) to the satisfaction of human wants.

In this context, the "key element of the system" — "the wide diffusion of the authority and resources necessary to experiment" — would constitute a corresponding particular combination of responsibilities of the OSTP, of its director, and indeed, on occasion, of the president himself, upon whose informed judgment would ultimately depend a "presidentially encouraged implementation" of the particular "experiment" in question.

As it happens, there have recently been indications of such "presidentially encouraged implementation" of at least three potentially grand experiments at sea, each of which promises to become tremendously important to the general strategic picture for the United States. The first of these as yet nascent "experiments" can be identified with the seawardly oriented part of COSU itself. The second can be similarly identified with the seawardly oriented part of the U.S. Global Change Research Program. And the third such "experiment" is only now becoming obviously identifiable with a myriad of long-standing, as well as several very new, unclassified activities of the United States Navy.

Moreover, to our great good fortune, these three potentially grand experiments at sea are all of a piece! And yet, to be sure, each of these three "experiments" is aimed toward the satisfaction of a distinctly different kind of human want.

Thus, the first of these — the seawardly oriented part of COSU — is in essence aimed at raising the standard of living, improving the quality of life, and significantly increasing the overall wealth of American society.

The second of these — the seawardly oriented and as yet least developed part the Global Change Research Program — is clearly aimed toward the distant and financially costly but ultimately rewarding goal of satisfying the most profound human want of all: namely, the need to achieve the full recovery and the permanent maintenance of planet Earth's capacity to support itself.

And the third "experiment" among these — which would directly involve the United States Navy — can now be expected to introduce an additional dimension to the Navy's traditional national security role that would be sharply focused upon (i) protecting the peaceful at-sea implementation of each of the preceding two potentially grand experiments against the possibly aggressive conduct of hostile trespassers, and (ii) actually joining forces with both of the latter "experiments" in the pursuit of whatever objectives of theirs might coincide very closely with certain unclassified but crucially important naval objectives.

HOW CAN WE GO ABOUT "EXTENDING THE REACH"* OF SUCH A "SYSTEM" FROM A NATIONAL TO A GLOBAL LEVEL?

In 1920, H. G. Wells wrote presciently[6] about "the inevitable fusion of the world's economic affairs into one system," whose "economic organization will be an exploitation, by...the common government for the common good, of *all* natural wealth (including, in the present instance, *ocean assets*) and *every* fresh possibility science reveals (including, again in the present instance, primarily *new* R&D assets pertaining thereto)" (emphasis added). Certainly, therefore, it is not too soon, 71 years later, for those involved in "(innovative ocean engineering) *technology and organzation*" to undertake the task that must inevitably be fulfilled — not just at a national but rather at a global level.

With this injunction in mind, let us next consider the relative positions of the three potentially grand experiments at sea now under discussion, with respect to the progression of each such "experiment" from a national to a global level.

It is here that one will perhaps find, in respect of COSU in particular, an appropriate reason for the present choice of this paper's title and basic theme. The U.S. Global Change Research Program, while still a strictly national effort in a formal sense, has already adopted that kind of overall approach which is required by the global nature of its mission. As for the third member of the "Triple Alliance," it, like COSU, has yet to go about "extending the reach" of its kind of naval activity from a national to a global level.

In any event, the rest of the present paper should be couched in the kind of global terms more appropriate to the U.S. Global Change Research Program than to the other two members of the "Triple Alliance." For, in fact, the U.S. Global Change Research Program should be expected to increase the scale of its seaborne operations, over the coming years, considerably faster than the other two members will be able to increase theirs; and, in doing so, it should still be able to accommodate, as participants in its own seaborne operations, correspondingly increasing numbers of "Triple Alliance" personnel.

Within the Global Change Research Program, measures could be taken that would provide for a wide range of at-sea in situ observations and research essential to the understanding of global change, while simultaneously responding effectively to global environmental change itself. Some of these measures would possess the further capability to curb the burning of fossil fuels through the simultaneous production and use of hydrogen energy derived from ambient renewable ocean energy sources. To implement such conceivable measures might therefore be all to the good, in spite of the widely prevailing concern — as quoted by the *Washington Post*[7] — "that scientific projections of global warming are too uncertain to justify measures to curb the burning of fossil fuels." Indeed, among all such conceivable

* Here, credit for introducing the phrase "extending the reach" should be given to the chairman and members of the Conference Committee for DOI 91 (Defense Oceanology International 91), held in Brighton, UK, 6-8 March 1991. This phrase was their very felicitous choice of the theme for DOI 91.

measures, none could provide the *Global Change Research Program* — in its proper role as global precursor of the entire "Triple Alliance" — with advantages equal to those that would follow from utilization of the concept of a totally submersible wave energy stabilized platform capable of providing, anywhere on the high seas, all of the hydrogen that might be required as fuel for manned and/or unmanned undersea vehicles.

THE WEST GERMAN VIEW OF GLOBAL CHANGE RESEARCH

It is interesting, in this connection, that in April 1988, under the mandate of West Germany's Federal Minister for Research and Technology (BMFT), an Ad-hoc Committee composed of twelve experts and leading figures published an exhaustive report entitled "Solar Hydrogen Energy Economy." Here, their task was "to advise the Minister and to make recommendations for solar hydrogen policy,...in particular (with respect to) the possibility of and/or necessity for a solar hydrogen energy economy... The problem area of CO_2 was to be taken into particular consideration...in connection with the need for action to limit the release of CO_2 this century."

Among the Committee's recommendations for the period 1988-1992, the development of hydrogen combustion engines is especially relevant to the new ocean technological concept, in the particular context of its potential application to at-sea in situ observations and research required by the Global Change Research Program. What the committee has recommended in this regard is (i) that developmental "work of this kind is only meaningful in conjunction with comprehensive demonstration projects supplying sufficiently large quantities of hydrogen;" and (ii) that "further (demonstration) projects are (only) worthwhile if answers can be found to further R&D questions in market niche applications which are significant for the energy economy."

Essentially the same considerations that have been stressed by the Committee are reaffirmed in the following excerpt from Toepler: "The investigations carried out so far have shown that the use of hydrogen in vehicles can be a feasible alternative which is likely to play a major role on a long-term basis... On a medium-term basis, use (of hydrogen) in market niches should be aimed at in order to advance the technological testing on the one hand, and to be in a position to quickly respond to a potential deterioration of the CO_2 problem on the other hand. The following possibilities of application might constitute such 'niches':

- use of hydrogen which results locally under economic conditions, for example as a by-product of the chemical industry;
- use in vehicles with extremely low exhaust gas limits; and
- use within the framework of major demonstration and research programmes for extensive application of regenerative energies."[8]

RELEVANT WEST GERMAN INDUSTRIAL POLICY

A somewhat earlier paper by Toepler and Feucht reported detailed results on an ambitious demonstration project in Berlin, where a fleet of ten Daimler-Benz vehicles, designed for hydrogen operation, were driven by different customers between October 1984 and March 1988, yielding a complete test distance of more than 250,000 kilometers. The following is an excerpt from the concluding section of their paper: "The research and development work of Daimler-Benz in the field of hydride vehicles has demonstrated that all components of a hydrogen driven car with metal hydride storage system can be worked out to a performance comparable to conventional cars and suitable for the use of normal customers over a long period."[9]

Toepler and Feucht were evidently at pains to convey the outstanding importance of Daimler-Benz's successful completion of its first major demonstration project directed toward the goal of a viable hydrogen driven car. However, those authors were also aware that, as has been stressed by the above mentioned Ad-hoc Committee, certain "key areas of solar energy technology" must be regarded as areas wherein "the Government should make provision for future needs. This responsibility cannot continue to be borne to such a great extent by industrial firms, which are dependent in the short and medium term on markets bringing in a return... The danger of a 'broken thread' following the withdrawal of some industrial enterprises from research and development...in the coming years, and the possibility of a shortage of funds for...the components of hydrogen energy technology in the 1990s as a result of the high expenditure requirements recognized by the committee...have to be *evaluated* by the Federal Government also *from the standpoint of industrial policy*."[9]

A POTENTIAL NEW CONSENSUS ON GLOBAL CHANGE RESEARCH

It is precisely from this standpoint of industrial policy that the foregoing statements by the Ad-hoc Committee are so relevant to the new ocean technological concept that has been described above in the particular context of its potential application to at-sea in situ observations and research of the many kinds required by the Global Change Research Program.

For consider how favorably any number of automotive vehicle firms with resources comparable to those of Daimler-Benz might look upon the prospect of joining forces with the U.S. Global Change Research Program in its pursuit of certain required kinds of at-sea in situ observations and research, provided that such joint action could thereby automatically acquire a market niche character capable, in the aggregate, of bridging the gap between smaller applications of solar hydrogen and an eventual solar hydrogen energy economy — simply through shared utilization of the new ocean technological concept.

Strange as it may seem at first, the at-sea in situ activities included under the U.S. Global Change Research Program afford a tremendous opportunity for the automotive vehicle industry, worldwide, to advance the state of the art of its own land-vehicle development activities in the direction of transition from the present oil economy to the only successor thereto that is both potentially the soonest available and by far the most acceptable of all: the *solar hydrogen energy economy*.

Here, in fact, the potential for worldwide involvement of the automotive industry is just one of a number of examples that illustrate that "this new technology is capable of extending the scope and accelerating the development of...means to augment substantially, and over a very broad front, the oceanic component of the Global Change Research Program." And here again, the same potential for joint action, involving the automotive vehicle industry worldwide, can be cited to illustrate that an action taken not just in response to global environmental change, but also with the utmost certainty that, by virtue of its uniquely *market niche* character, would simultaneously have profoundly favorable global economic effects.

THE UNDERLYING NEW OCEAN TECHNOLOGY CONCEPT

To further an understanding of the use of hydrogen fuel derived from wave energy for submersible vehicles, a graphic devised by Vadus is shown as Figure 1.[10] This figure portrays a process of refueling, with hydrogen, each of a potentially large number of autonomous underwater vehicles (AUVs), whenever that particular AUV runs short of hydrogen fuel. In the present, unelaborated context, the AUVs would be serving collectively to build a data base required by the U.S. Global Change Research Program — and of doing so *anywhere* on the world ocean, from sea level to sea bottom. Docking of the AUVs, and the source of their hydrogen fuel, would be provided by a totally submersible, wave energy extracting — and *wave energy stabilized* — platform of unique design invented by the present author.[11]

Here, in view of the immense magnitude of the task confronting the U.S. Global Change Research Program in its pursuit of *all* essential at-sea in situ observations and research, it might be useful to consider the following assessment by Vadus of the magnitude of the far less ambitious task already entered upon by NOAA, working in cooperation with the U.S. Geological Survey (USGS): "The U.S. Exclusive Economic Zone (EEZ) is the objective of a very ambitious (seafloor) survey program covering 3.9 billion acres... The USGS has completed the survey of 60 percent of the EEZ...with a resolution of about 500 meters... This resolution provides a broad look without the detail needed to conduct many site specific projects. To provide the increased detail, NOAA (and) the USGS (are) using the Sea Beam system...with a depth resolution of about 15 meters... This higher resolution NOAA system has completed about 2 percent of the EEZ, using four Sea Beam survey ships. At this rate, it will take about 100 years to complete."[12]

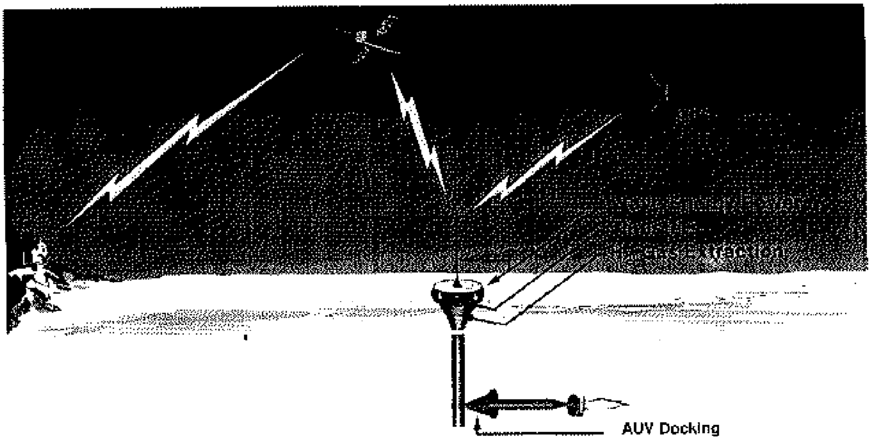

Figure 1. Schematic of Wave Energy Stabilized Seagoing Platform Designed for Refueling Hydrogen Driven AUVs.

On the other hand, the following assessment by Stuart, which addresses a different but related and comparably forward-looking technical objective, makes one mindful that

> ...as we enter the last decade of this century the realization of practical and economically feasible applications of unmanned undersea vehicles (UUVs) to both military and commercial activities seems more likely than ever before. Efforts are underway in both sectors to demonstrate such applications as deep ocean exploration, oceanographic data collection and offboard sensor adjuncts to submarines and surface ships. In fact, not since the 60s and 70s has the investment been as great, and during the interim period our progress in computers and automation has begun to produce the technologies needed to implement fully autonomous systems... However, robust reliable autonomous systems that can operate over long periods unaided by human intervention remain to be demonstrated, [and the accomplishment of that goal] will be paced by developments such as autonomous sensor systems and controllers, high density and efficient energy and propulsion systems, and practical methods for communication where interaction with humans is necessary to meet mission goals or to improve system reliability."[13]

For anyone familiar with the capabilities of the "platform of unique design" portrayed in Figure 1, the assessments by Vadus and Stuart, when considered together, would be clearly indicative of what can be done to reduce, profoundly, not only the "immense magnitude of the task confronting the U.S. Global Change Research Program," but also the time that would elapse before viable AUVs could become commercially available.

By the same token, use of the "platform of unique design" to provide identical opportunities "to advance the technological testing" of hydrogen combustion engines in a market niche setting would enable the automotive vehicle industry, worldwide, to profoundly reduce the time that would elapse before viable hydrogen driven cars could become commercially available.

AN ELABORATED AND MORE COMPREHENSIVE CONCEPT: THAT OF A "MARITIME SETTLEMENT"

One may, indeed, go beyond the single platform configuration that has been central to this discussion. It has been shown by the author[14,15] that, by a straightforward process of extension of such a *single* platform configuration, one may elaborate therefrom a more complex, *mutiple* platform configuration whose component seagoing platforms can, when suitably deployed, surround and shelter any (presumably much larger) preselected surface area anywhere on the high seas.

It has furthermore been found that, under the protection of such a multiple platform configuration, the way then lies open, for the first time, to establish *anywhere* on the high seas an entire, potentially permanent, and in almost every respect autonomous "maritime settlement" having — among others -- the following attributes:[14,15]

Such a "maritime settlement" could be wholly dedicated to engaging simultaneously and safely, in all weathers, in any particular combination of scientific, industrial, commercial and/or military activities that meet the research, development, demonstration and/or security needs of all occupying parties.

- Firms acting jointly as one party that separately aims to produce viable hydrogen driven cart
- Firms acting jointly as a second party that separately aims to produce viable AUVs and
- In every instance, government agencies, academic institutions and private firms acting jointly as a third party that separately aims to complete a particular required subset of at-sea in situ observations and research.

With respect to all of the foregoing activities, a previously agreed-upon common objective will have instilled into all three parties an unswerving commitment to ensure that their mutually cooperative efforts are able "to acquire a unique market niche character capable, in the aggregate," of bringing closer to reality "an eventual solar hydrogen energy economy."

A UNIQUE MARKET NICHE ADVANTAGE, FREE ACCESS TO WHICH IS AFFORDED BY THE WORLD OCEAN TO ANY "MARITIME SETTLEMENT"

Under the same protection of the multiple platform configuration, one can, of course, also envisage setting up a collocated wind farm at sea, the individual platforms of which have been found[14,15] to function most cost effectively when permitted to differ from the original (wave energy extracting) single platform configuration only in relatively minor ways.

From estimates of worldwide wind energy resources, one can ascertain the contrast between prevailing average wind speeds over the world ocean and over the continental landmasses. This contrast markedly favors the world ocean over the continental landmasses as the area of choice for converting wind energy at well above the minimal average wind speed (approximately 13 miles per hour) below which present state-of-the-art wind turbines cannot operate cost effectively.

In this connection, it has been authoritatively stated[16] that "so far...no system designs are capable of producing energy at the $0.04-0.06 per kilowatt-hour level required to compete with existing energy sources *in areas with moderate, 13 mile per hour average wind speeds*" (emphasis added). Moreover, there is very little room left for even minor improvements in the cost effectiveness of present wind energy system designs.

On the other hand, because of the cubic dependence upon wind velocity of the power in the wind itself, it certainly makes more sense to bet on ocean-based, rather than on land-based, wind farms. In the past, of course, such ocean-basing of wind farms was never possible, simply because of the inability to cope with violent storms at sea. But now, when "maritime settlements" have, in effect, already surpassed the prevailing state-of-the-art, ocean basing of wind farms is just as feasible as, and far more cost-effective than, land basing of wind farms.

Here, then, are two entirely new factors which, when exploited, can contribute immensely to bringing about the unique market niche advantage that would follow from utilization of the "maritime settlement" concept discussed here: namely, (i) the unprecedented possibility of fully exploiting simultaneously *both* the wave energy resources and the wind energy resources of the world ocean; and (ii) the unprecedented possibility of basing wind farms anywhere on the world ocean — either one of which possibilities could lead to an unprecedented conversion of renewable ocean energy at well below the $0.04-0.08 per kilowatt-hour level.

A STRATEGY FOR IMPLEMENTING AN INTERNATIONAL GLOBAL CHANGE RESEARCH PROGRAM TO PAVE THE WAY FOR A "TRIPLE ALLIANCE" OF GRAND EXPERIMENTS AT SEA

It is the author's belief that an integrated plan directed toward the implementation of an evolving international Global Change Research Program might reap major benefits from undertaking a proper role as global precursor of the "Triple Alliance" of potentially grand experiments at sea — by taking the earliest and fullest advantage of those technological advances which have led to (i) an unelaborated concept of a single seaborne platform configuration possessing certain unique attributes, and (ii) an elaboration thereof that can perhaps best be described as a more comprehensive concept: that of a "maritime settlement." It is also the author's belief that the evolving international Global Change Research Program affords what can only be regarded as the first and the best medium through which productive use of the technological advances might be undertaken on a global scale.

As for how the introduction and implementation of these concepts might either pace or be paced by the international Global Change Research Program, the author is not yet fully prepared to present any specific strategy at this time. However, he already does have in mind certain intimations of such a strategy.

For example, this author would recommend that an initial period be specified, during which implementation of the above concepts should be confined to the EEZs (or their equivalents) of all countries bordering on the world ocean; and during which the deployment of both single platforms and "maritime settlements" should be regulated in such a manner that the former will have ready access to the facilities of the latter at all times and in all modes of deployment .

This author would also recommend that, during the initial period, there should be available to each single platform every needed means of communication and transportation (passenger or freight) that is available to all "maritime settlements." Again during the initial period, any "maritime settlement" lacking a given facility should have ready access to another, nearby "maritime settlement" for which arrangements have been made for that facility.

Another recommendation that deserves to be tested experimentally, and that could easily be followed up during the initial period, would be to explore the at-sea behavior of what might be called "minor versions" of the "maritime settlement." Thus, one might consider an extremely simple example that would consist of only five platforms, four of which could be single platforms deployed at the four corners of a square, while the fifth, placed at the center of the square, would not only be surrounded and sheltered by the other four, but would also be nothing other than one of the wind-turbine-supporting, single platforms that make up a wind farm of the kind already described above.

At the opposite extreme would be a further, far more demanding recommendation: one whose implementation will have to wait out a lead time of about a decade for the conversion from kerosene to hydrogen as the aviation fuel of the future. Already there is a shortage of space for the many new airports that are needed to serve the coastal cities of the United States. And for those cities the only solution will be to locate the required new airports offshore, at what might be called "maxiversions" of the "maritime settlement," where wind farms of the kind described above can provide hydrogen aviation fuel while easily gaining, thereby, "a unique market niche advantage" over all competitors.

And finally, this author would suggest that another country among those which are chief contributors to the CO_2 problem — namely, Brazil — might follow suit by setting the same example, at a comparable level from the point of view of its strategic importance, and yet in a different context that bespeaks its own peculiar national condition. For that national condition is now such that Brazil, in the process of setting such an example, should simultaneously make every effort to redirect the lives of its citizenry away from their ongoing rapid destruction of its tropical rain forest and toward their productive use of its most valuable national asset: its thousand-mile-long EEZ.

The author would like to express his thanks to Joseph R. Vadus for useful discussions, and for permission to reproduce in Figure 1, a related graphic devised by him.

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Trends in
Resource Development

18

Environmental Implications of Offshore Sand and Gravel, Shell, and Placer Mining in the U.S.

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ABSTRACT

The Minerals Management Service (MMS), United States Department of the Interior, has a mission to investigate the potential of the U.S. offshore as a source of hard rock minerals and to assure that future development of such minerals is accomplished in an environmentally safe and sound manner. In carrying out this mission, the MMS's Office of Strategic and International Minerals (OSIM) is conducting and participating in a number of cooperative programs and projects with coastal states that will evaluate the economic as well as the environmental implications of offshore mining in specific areas. Emphasis is being placed on the examination of offshore deposits of sand and gravel, shell and placer minerals to provide material for beach nourishment, construction aggregate, and industrial minerals. Recognizing that some degree of preliminary environmental information is necessary for initial policy and program decisions at both the headquarters and regional levels, OSIM has embarked on a generic effort to examine the possible environmental effects associated with offshore sand and gravel and placer mining and to provide environmental information applicable to all U.S. offshore areas. Site-specific environmental studies will be developed by the MMS regional offices for areas where near-term lease sales for specific commodities are indicated.

INTRODUCTION

In 1953, the Outer Continental Shelf (OCS) Lands Act (OCSLA) (67 Stat. 462) established federal jurisdiction over the submerged lands of the continental

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shelf seaward of state boundaries. The Act charged the Secretary of the Interior with the responsibility for administering minerals exploration and development on the OCS. It also empowered the Secretary to formulate regulations so that the provisions of the Act might be met. Section 8(k) of the OCSLA provides specific legal authority and responsibility for the leasing of minerals other than oil, gas, and sulphur in the OCS. This authority and responsibility exercised in conjunction with some 20 other sections of the OCSLA, which are applicable in whole or in part, and other laws, provide the Secretary of the Interior with adequate flexibility and guidelines to establish and administer an OCS minerals exploration and development program. Regulations to govern activities associated with OCS minerals exploration and development have been promulgated by the Minerals Management Service (MMS) including: geological and geophysical (G&G) prospecting, and scientific research (30 CFR Part 280), leasing (30 CFR 281), and postlease operations (30 CFR Part 282).

Subsequent to the passage of the OCSLA of 1953, the Secretary of the Interior designated the Bureau of Land Management as the administrative agency responsible for leasing submerged federal lands and the Geological Survey for supervising production. In 1982, the MMS assumed these responsibilities. To meet its responsibilities, the MMS has four priority goals for OCS nonenergy minerals; these are: (1) to safeguard the ocean and coastal environments by assuring that all OCS mineral activity is environmentally sound and acceptable; (2) to evaluate and achieve the potential of the U.S. OCS as a domestic supply source for strategic and other nonenergy mineral resources; (3) to assure that OCS mineral activities are fully coordinated and compatible with other uses of the ocean; and (4) to provide an effective consultation process for the coastal states and the federal government on offshore minerals.

The National Environmental Policy Act of 1969 requires that all federal agencies use a systematic, interdisciplinary approach that will ensure the integrated use of the natural and social sciences in any planning and decisionmaking that may have an effect on the human environment. The MMS efforts in this aspect for the OCS oil and gas leasing program has included Environmental Impact Statements (EISs), Environmental Assessment Teams, marine environmental data acquisition and analysis, literature surveys, socio-economic analysis, public conferences, and special studies (toxicity studies, oil-spill trajectory analysis, etc.).

The MMS has not, up to this point in time, sponsored a great deal of environmental study in the area of nonenergy minerals, due to the relatively low level of activity. However, with the promulgation of the regulations cited above, and recent research undertaken to locate and evaluate various OCS hard mineral deposits of potential economic value, there does exist the possibility of offshore hard mineral development opportunities for various mineral commodities in the near-term, particularly for sand and gravel, shell, and placer minerals. The potential for development of these mineral resources is due not only to their apparent commercial need, but also because the technology presently exists to mine them. In keeping with environmental initiatives recently established by the agency and to fulfill National Environmental Policy Act requirements, the environmental consequences and impacts associated with development of these resources will be carefully evaluated and considered during any future programmatic undertakings.

U.S. OFFSHORE SAND AND GRAVEL, SHELL, AND PLACER DEPOSITS

Sand and Gravel

Sand and gravel deposits are the most widespread and abundant of the surficial marine mineral resources considered to be of potential commercial or industrial value. Sand and gravel can be used as construction aggregate or as material for beach nourishment. Although these resources are large, many deposits may not be of the proper quality, nor in the proper environmental setting for utilization. Thus, offshore sand and gravel resources must be evaluated in a manner that establishes quality and quantity in relation to regional requirements and the environmental consequences associated with recovery.

Deposits of offshore sand and gravel are similar in many respects to onshore deposits; quality and quantity is largely a function of the source material, the transport medium, and the actual physical processes involved in the ferrying of the material to its present site.[9] Deposits form by concentration of materials through processes similar to marine placer formation. In middle and high latitudes, deposits commonly result from reworking of glacial or fluvioglacial materials originally deposited during the Pleistocene epoch. Pleistocene shoreline features, beach ridges, and submerged terraces often consist of relict sediments. Sand and gravel can be extracted from such locations without disturbing the equilibrium of the modern shoreline.[4] To a great extent, this has been demonstrated during marine mining activities conducted offshore the British Isles.

Abundant sand and gravel resources are located on the U.S. OCS, largely represented by a widespread shelf sand sheet and a variety of lenticular sand bodies that include shoals, relict beach ridges, and buried channel deposits. Generally, relict sands are located seaward of the recent sands, but can be found essentially at any depth. Estimates of the volumes of sand and gravel resources on a provincial basis for the U.S. Atlantic Outer Continental Shelf are 2.0×10^{12} cu. m. in the North Atlantic Province, 2.6×10^{12} cu. m. in the Middle Atlantic Province and 2.2×10^{11} cu. m. for the South Atlantic Province.[3] Although sand resources are abundant throughout the shelf area, gravel most frequently appears on the glaciated shelf of the Northeast. Gravel deposits occur offshore New York in large alluvial fans deposited by fluvial processes associated with the Hudson River. Residual gravels derived from glacial-related sediments are concentrated by tidal processes on Georges Bank offshore Massachusetts.

North of Long Island, New York, extensive sand deposits are associated with marine processes linked to and following past glaciation. Glacial and post-glacial sediments have been reworked into significant sand and gravel deposits, often unevenly distributed across the continental shelf. From Long Island to Cape Lookout, North Carolina, the shelf received enormous volumes of detritus from fluvioglacial sources; south of North Carolina, glacial and fluvioglacial influences are absent. Sand deposits are thin, discontinuous surficial sand sheets or sandy shoals. As the water becomes warmer in lower latitudes, carbonate content of the sands increases.

In the Pacific, about 40 km. offshore Honolulu, a sand and gravel deposit containing approximately 350 million cu.m. of material covers an area of about 78 sq. km. On the West Coast, sand and gravel deposits on the continental shelf offshore Oregon and Washington encompass an area of over 225 sq. km. and are estimated to contain over 2.5 billion cu.m. of material.[7] Offshore California, sand and gravel deposits located on the San Pedro and San Diego shelves appear to be the result of wave erosion or are submerged portions of Pleistocene shorelines. Proximity to commercial markets certainly makes these deposits potential candidates for development.[5]

Several MMS-State task forces are actively involved in evaluating the potential of specific offshore sand and gravel deposits. A joint Federal/Multi-State Task Force composed of the MMS and the States of Alabama, Louisiana, Mississippi, and Texas is presently conducting an investigation of the geologic, engineering, economic, and environmental aspects of the Ship Shoal area offshore Louisiana. The shoal may represent a potential source of sandy material for beach nourishment and restoration of Isles Dernieres and the nearby Bayou Lafourche shoreline.

In the New England area, the New England Governors' Conference in cooperation with the MMS is investigating the current and future demands for aggregate material within the New England States to determine if projected needs will exceed traditional supplies. Should the study conclude that the projected demand for sand and/or gravel is likely to exceed the traditional local supplies, a recommendation could be made for a task force to evaluate onshore supplies as well as offshore deposits and their ability to meet the demand.

Shell Material

Offshore shell material is of potential commercial value as it can be used, like sand and gravel, as construction material for road building and other industrial applications. Calcareous shell deposits are formed by the destruction of marine shells and subsequent concentration of fragments by hydrodynamic processes or by in-situ accumulation of beds of shells. Concentration of shell sands and fragments is different from that of mineral sands and gravels. Shells respond differently according to their respective shape and specific gravity. Such differences can lead to segregation and concentration into deposits unlike mineral sands. Most offshore shell accumulations are relict deposits and occur most frequently in the lower and middle latitudes.

The Atlantic, Gulf of Mexico, and Pacific continental shelves possess significant shell deposits, as do shallower areas near the Pacific Islands. Oyster beds have been extracted from San Francisco Bay and from nearshore areas of Virginia and North Carolina. In the Gulf of Mexico, widespread reported occurrences of offshore shell deposits are likely to be explored as a source of construction material and calcium carbonate.

Placer Deposits

Placer mineral deposits represent a potential source of valuable industrial minerals. Placers are formed by the concentration of heavy, chemically inert mineral particles from the weathered debris of igneous, sedimentary or metamorphic source rocks. Transported principally by aeolian, fluvial, or ocean processes, placer minerals are often concentrated in beach and offshore sand deposits by wave and current action. Most marine placers occur on the continental shelves and are commonly associated with surficial sand and gravel deposits. During advances and retreats of the sea associated with the glacial era, placers were formed, reworked, destroyed, or preserved in the surficial sand sheet. The modern shelf break zone corresponding to the greatest retreat of the sea is as much as 150 m below present sea level.[2]

Heavy minerals, especially those containing titanium, are associated with surficial relict sand bodies that range in thickness from about 20 to 140 m and are widespread along the entire Atlantic continental shelf. Resources containing 1 to 4% heavy minerals have been estimated at approximately 1.3 billion cu.m for the Atlantic shelf.[6] On the Pacific shelf, heavy mineral sands of various grades and composition are estimated at about 2 billion cu.m.[11] A joint Federal-State of Georgia Task Force was established in October 1986 to study and evaluate the phosphate data, as well as heavy mineral placers and other strategic minerals offshore Georgia.

Gold and other heavy mineral sand deposits occur in relict beaches, buried river channels, and reworked Pleistocene gravels. Titanium and zircon sands are believed to be widespread throughout the Pacific continental shelf. Placers of chromite occur as black beach sand deposits off the southern coast of Oregon. Extending southward from Coos Bay, Oregon to northern California, these placers are situated in unconsolidated sediments of modern and older terraces.[1] In May 1988, Governor Goldschmidt of Oregon requested that the MMS establish a Federal-State of Oregon Task Force to undertake a technical analysis of environmental impacts and economic potential of future extraction of strategic metals in ilmenite-bearing black sand deposits known to exist offshore. A cooperative agreement was subsequently signed in September 1988.

Presently, resource estimates for placers in Alaskan shelf sands are not available. However, the area offshore Alaska has a high potential for placer deposits of gold, silver, platinum, and other minerals. Gold placers are expected to be present on the eastern shelf of the Bering Sea. Because the Seward Peninsula is an important region for placer gold, offshore gold placers are expected to be present on the outer continental shelves of Norton Sound and the Bering Sea. Bering Sea sediments offshore Nome are reported to possess concentrations of gold particles of 1 mm. or more, occurring in older seafloor gravels overlying glacial deposits. Submerged beach deposits commonly have the greatest gold content where such beaches cross glacial deposits. Due to the known presence of gold placers in State waters in the Norton Sound area, the MMS has been involved in a coordination team effort with the State of Alaska, which has resulted in the preparation of an environmental impact statement for a proposed Norton Sound Minerals Lease Sale presently scheduled for mid-1991.

ENVIRONMENTAL CONSIDERATIONS

During development planning for offshore sand and gravel, shell, or placer mineral deposits, the marine environment must be considered as an integrated environmental system composed of geological, chemical, physical and biological aspects. The principal environmentally-related components are discussed below.

The geological setting, specifically the regional geomorphology, plays a major role in the evaluation of surficial deposits, particularly those situated in water depths of less than 100 ft.[8] Alterations in seafloor morphology caused by the addition of mounds and hills, or by the formation of trenches or pits caused by excavation can result in significant impact on the forces associated with the processes that shape the shoreface and coastline. Textural alteration of the bottom surface sediments must also be considered. Seafloor sediment textural properties, such as mean grain size and sorting coefficients, can be altered by the selective removal of large quantities of material. Large amounts of fine-grained material settling through the water column and accumulating on the sea floor can potentially result in alteration of the existing characteristics of the surficial sediment.

Chemical assessment involves analysis of chemical constituents and concentrations in the water column, as well as the material and interstitial fluids within the sediment itself. Chemically-related environmental problems can develop during disturbance of bottom sediments that contain significant quantities of nutrients, trace elements, or toxins. Most important is the detection of potentially hazardous materials. Certain heavy metals may be present in an active or inactive state under specific geochemical conditions. Disturbance of the sediment could alter the present geochemical conditions (the redox potential for example) in such a way that inactive heavy metal chemical species may change, become active, and possibly enter the marine food chain. Heavy metals in interstitial waters associated with clay and organic-rich sediments have been routinely detected by atomic absorption analysis in the parts per million ranges. Therefore, if concentrations of clay or organics are encountered during sediment sampling, a geochemical analysis should be conducted of the water column, clay fluids, fine-grained sediments and organics.

Physical oceanographic changes resulting from geomorphic alterations are one of the physical factors which must be considered. Regional geomorphology may assume a major role in the decision to mine an offshore deposit. Significant geomorphic changes to an offshore body may result in alteration of bottom currents, longshore currents and wave refraction patterns. Changes in bottom and longshore currents can have a major impact on the local sedimentary budget, which may in turn affect local sediment supply patterns; alterations in the wave refraction pattern of an area may have an effect on coastline erosional processes. Such physical alterations ultimately may result in changes to elements such as temperature, current patterns, amount of suspended particulates, the nature of the sea floor and substrate, light penetration, photosynthesis and the introduction of new habitats that, in turn, result in impacts to the local biology.

The direct physical effects of the mining activity on the local biology of an area is one of the most critical factors which must be carefully evaluated before operations take place. An obvious point of impact during marine mining, and particularly dredging, is on the benthic communities. Clearly, there will be some degree of direct mortality associated with the mining activity. Also, as mentioned above, the physical disruption that takes place can alter benthic habitats which plays a major role in determining if, or to what extent, recolonization of an area occurs after cessation of mining operations. The relationship between the benthic organisms and the bottom sediments is the most important factor in determining the degree to which recolonization ultimately occurs. If the sediments in the project site after mining differ markedly from the original composition, then only limited recolonization may occur. The process of recolonization is largely dependent on the environment at-large and the nature of the sediment and habitat change. Conditions may be such that recolonization and repopulation is slow, but complete, and/or that the population may be significantly different from the original.

Indirect effects to local biology may also be induced by increased turbidity within the water column. Growth and reproduction of some organisms, such as bivalve mollusks, may be affected by high turbidity. Mining activities can also interfere with the seasonal migration of some anadromous fish species. Both bottom-dwelling and water column fish populations may be affected by the habitat disruption and sediment changes due to loss of specific food sources. Water quality changes associated with the increased load of material within the water column may result in the inhibition of reproduction and growth in some organisms while stimulating other populations, such as phytoplankton, due to the increased nutrient content. Phytoplankton production may also be affected by increased turbidity, which alters photosynthetic processes by limiting the amount of light entering the water column.[12]

All of the environmental factors mentioned above must be carefully evaluated and considered before and during mining operations within an area.

ENVIRONMENTAL STUDIES

As the potential for further exploration and possible development of offshore sand and gravel, shell, and placer minerals on the U.S. OCS increases, the environmental considerations cited above will generate a need for technical information to aid MMS in making prelease or postlease decisions. The OCSLA requires the Secretary of the Interior to conduct studies and monitoring or to obtain environmental information from appropriate sources and to use this data in decisionmaking relating to mineral exploration and development activities. Two general categories of studies are likely to be undertaken:

- Generic studies to examine the effects of particular types of mining operations on various aspects of the physical, chemical, and biological environments. Studies examining various types of mitigation techniques may also be undertaken. Such information would be used for decisionmaking and in decisionmaking documents for all proposed offshore mining operations of a similar nature.
- Site-specific environmental studies in areas where offshore mining is proposed or where mining appears feasible in the near future.

Wherever and whenever possible, existing or planned oil and gas environmental studies will be utilized or contracts amended to provide environmental information for hard minerals leasing decisions. The MMS Environmental Studies Program (ESP) has produced, and continues to produce, a significant amount of scientific and technical information, some of which may be applicable to environmental analyses and decisions related to nonenergy minerals mining on the OCS. The ESP information database covers technical subjects such as ocean currents and pollutant transport mechanisms, air and water quality, distribution and abundance of commercially or ecologically important and endangered species, oceanographic hazards, arctic hazards, and social, cultural, and economic conditions in coastal areas.

With the understanding that the current subject content of the MMS ESP cannot provide all of the information required, OSIM has embarked on an initial effort to develop several generically-oriented environmental studies. These studies will be designed to provide information to assist in making initial programmatic offshore hard mineral leasing decisions at both the Headquarters and Regional levels, as well as furnishing generic information useful during preparation of Regional lease sale-specific documents; these efforts are described below. The MMS Regional Offices will formulate site-specific studies for areas in which near-term lease sales are indicated.

Literature Search Study

The purpose of this study, scheduled for procurement in Fiscal Year 1991, is to survey, analyze, and synthesize existing literature regarding the potential environmental impacts of marine mining on the environment and to have the information summarized in a single manuscript. The search will not be specific to sand and gravel, or placer mining, but will be oriented to include all types of mining operations and offshore minerals. This information is necessary to adequately assess the current level of knowledge regarding the potential environmental effects of marine mining on the marine, coastal, and onshore environments of specific regions or areas and to identify possible data gaps in advance of proposed mineral exploration and development activities. This information will be invaluable in lease sale EIS's and in other facets of the MMS decisionmaking process. The information gathered during this study will enable the MMS EIS analysts to better assess the potential impact of offshore mining in their regions and to ascertain areas in which further site-specific study is warranted.

Information to be accessed will include factors such as the following: impacts of marine mining on water quality and the seabed, on benthic and water column organisms and habitats, on recreational and coastal facilities; effects relating to the possible offshore disposal of waste material; and the effects of offshore and onshore processing and tailings disposal. General environmental analyses, as well as laboratory, field, and modeling studies, will be included in the literature search. The information synthesis will be designed, not only to provide an overall picture of the extent of environmental information available, but also to identify mitigating measures which can be implemented during offshore mining operations in order to minimize or preclude potential adverse impacts to the environment. Potential models that the MMS could use to predict the fate of material disturbed or discharged during actual mining operations will also be identified and analyzed.

Benthic Repopulation Study

As discussed previously in this paper, the immediate consequences of marine mining, such as dredging for sand and gravel, placer minerals, or other offshore mineral deposits will likely involve some degree of destruction or disruption to the habitat of benthonic invertebrate or other benthic organisms which lie within the path of the mining operation; sessile, non-mobile, or slow-moving organisms may be especially susceptible to impact. This population is generally a source of food for many water column-dwelling species. There also exists the risk of changes to the spawning grounds for fish or other marine species that spawn on the sea bottom, as well as long-term changes in the sea bottom population due to changes in the zones of distribution of different substrata and the subsequent modification of relations between the biological populations living in them.

A cursory survey of the existing literature base appears to indicate that, of the studies intended to detail the environmental effects of offshore dredging and mining, a relatively small percentage have focused on the seafloor impacts or mining site itself. The studies that have been conducted have placed primary emphasis on the extent and character of sediment resuspension induced by the mining operation, the impacts of turbidity plumes induced by surface discharges from the mining vessel, and the influence of these materials on local pelagic fish populations or the benthic communities found in the areas adjacent to the area being dredged or mined. Very little information appears to exist regarding the degree to which a mining activity affects benthic communities and their ability to repopulate after being directly affected by a mining operation.

OSIM is developing and hopes to procure in fiscal year 1992, a study designed to evaluate and gain insight into long-term effects by the nature of, and the degree to which, benthic organisms repopulate the seabed after a mining activity takes place in a coastal or shallow open-ocean area. The degree to which repopulation of similar benthic species occurs will also give indication as to changes in fish species in the area.

The study would entail coordination with a planned dredging activity, preferably on the U.S. East Coast, in an area composed of sandy substrate in order to approximate conditions similar to those which would be found in an area likely to undergo mining for sand and gravel resources, and where near-term prospects for mineral recovery appear favorable. The study area should be in waters of sufficient depth to simulate conditions found in the open-ocean.

Prior to the actual beginning of dredging, the current status of the seabed in the area to be dredged, in relation to benthic and fish communities, will need to be assessed. This will involve biological sampling and video observations, as well as a general review of the literature. After the dredging activity is completed, the seabed conditions will be monitored through biological sampling and video observations. Several continuous photographic and other biological sampling stations (control stations) will also be established in various locations on the seabed in the study area to provide a time-continuous record of seabed conditions and repopulation. Periodically, sampling would be conducted in the study area and photographs and specimens from the seabed stations will be collected to assess the degree to which repopulation is occurring. These observations would be continued for approximately 2 to 2.5 years, at which point the overall degree to which repopulation has occurred will be evaluated, and any changes in seabed or fish populations within the study area will be noted. The results of the study should be applicable to other planning areas and other areas of potential U.S. OCS hard minerals mining activities, particularly those areas that exhibit similar bottom substrates and benthic community compositions as would be found within the study area.

This information is necessary to at least preliminarily evaluate and assess the possible impacts of a sand and gravel or placer mining operation on benthic-dwelling organisms in a coastal or shallow, open-ocean area. These are the areas which are more likely to see mineral development and mining activity in the near-term. The information would prove invaluable in assessing the suitability of a proposed area of development in relation to the ability of the biota to survive a mining operation or to repopulate after cessation of mining activities. The information provided by the study might also be used to identify ways in which a mining operation can be conducted so as to minimize or preclude adverse impacts to the environment.

SUMMARY AND CONCLUSIONS

The U.S. offshore area is known to contain a wide variety of mineral resources of potential commercial importance to the nation. The most accessible commodities at this point in time are sand and gravel, shell material, and placer deposits. Prior to actual development of these resources, it is imperative that the potential environmental impacts of any marine mining activity be carefully considered and evaluated. During this assessment, the marine environment must be considered as an integrated environmental system composed of geological, chemical, physical and biological aspects.

The Minerals Management Service's Office of Strategic and International Minerals is working cooperatively with several coastal states to evaluate the economic potential and environmental impacts associated with future extraction of specific mineral resources within the offshore area. In order to provide some preliminary environmental information necessary for near-term policy and program decisions, OSIM has embarked on an initial generic effort to examine the possible environmental effects associated with offshore sand and gravel and placer mining. The office will continue in the future to develop studies to provide needed generic environmental information for future program decisions at both the Headquarters and Regional levels. Site-specific environmental studies will be developed by the MMS Regional Offices where near-term lease sales are imminent.

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The Potential for Fisheries Habitat Creation through Marine Aggregate Mining in the Bay of Fundy, Nova Scotia, Canada

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ABSTRACT

A large sand wave field has been delineated in Scots Bay, Bay of Fundy, Canada. It contains an estimated volume of 35 million cubic metres of coarse grained, well-sorted sand, in 17 m of water depth, that could be mined as a source of aggregate. Internal structures within the individual sand waves indicate that the field has grown during the last 5000 years. Repetitive seismic reflection surveys over the deposit suggest that it has migrated several hundred metres to the northeast over the past 25 years. A central line of convergence occurs within the wave field running from southwest to northeast suggesting that the deposit is in equilibrium with the strong currents of the Bay of Fundy. The sand wave field is developed on a basal transgressive gravel surface which occurs as an unconformity overlying a thick sequence of estuarine sediments. Diffuse acoustic returns on sidescan imagery indicate that the gravel lag supports a community of marine flora.

Fishing activity is intense on the gravel lag surface, as evidenced by a dense pattern of trawl marks at the seabed. However, fishing does not occur on the sand wave field because of the intensity of sediment transport. Potential mining interests have proposed that through removal of the sand in the wave field, a substantial area of similar habitat (gravel lag) to that presently fished will be exhumed. This is an example of how two seemingly competitive resource industries may co-exist and how the activities of one may benefit the other.

International Perspectives on Coastal Ocean Space Utilization
Phyllis M. Grifman and James A. Fawcett, Editors

INTRODUCTION

The Bay of Fundy is bordered on the southwest by the province of New Brunswick and on the east by the Nova Scotia mainland; covering a surface area of approximately 10,000 km^2 (Figure 1). Bowden[6] estimated in excess of 96 million m^3 of water moves in and out of the Fundy embayment with the daily tides. The average tidal stream velocities range from 0.5 to 6 knots[25] in a water column averaging 75 m deep. Residual currents (net velocities after removal of short-term fluctuations) indicate a movement of water into the Bay along the Nova Scotia side, a net movement out of the Bay around Grand Manan island and a general cyclonic circulation within the Bay.[14] The strong tidal currents have modified surficial sediments on the Bay floor and scoured many restricted narrow passages within the area.

A study by Swift et al.[30] described an extensive sand wave field in the Bay of Fundy. This data was updated by Miller and Fader,[26] employing a high-resolution seismic reflection system and sidescan sonar. This paper gives a brief review of the geology of the Bay of Fundy, describes the sand wave field and discusses the environmental aspects associated with its marine mining.

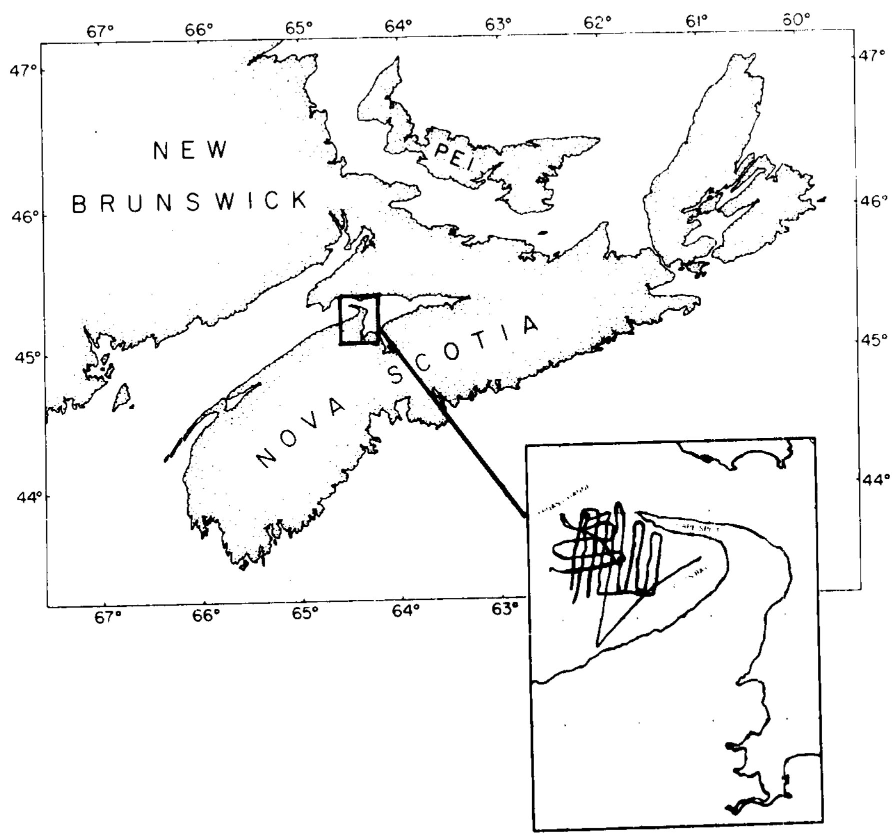

Figure 1. Location map

REGIONAL SETTING

Bedrock Geology

The oldest rocks within the Bay of Fundy are Pre-Pennsylvanian in age and include deformed Cambro-Ordivician-Silurian sedimentary and volcanic rocks also found on the adjacent land mass. Triassic rocks floor the Bay in a synclinal structure with the axis trending along the central bathymetric axis of the Bay.[34] Johnson[20] and Koons[23,24] suggested that the Bay of Fundy was formed by pre-Quaternary fluvial erosion of the Acadian Triassic Basin with the northwestern margin being a zone of normal faults from 2 to 10 km seaward of the shore. Swift and Lyall[31] concluded that the basin is a half-graben with a dominant central syncline and that the Bay has been incised into the red continental mudstones, sandstones and tholeiitic basalts of the graben. Also, that it reflects a former drainage basin starting in the Minas Basin to Truro region of central N.S. and continuing through the Bay into the Gulf of Maine, indicating a regime of subaerial erosion, later modified by glaciation. North of Grand Manan the Acadian Basin was a broad open syncline, while south of the island, three narrow troughs were identified[33,35] as tectonic basins within a Carboniferous-Triassic rift system.[4] The syncline plunges to the SW and continues along the Bay.

The Wolfville Formation consisting of red sandstone and shales was deposited in an alternating flood plain-alluvial fan type environment, while the Blomidon Formation was deposited in a lacustrine environment. The Scots Bay Formation at Broad Cove is also lacustrine. Stratigraphic thicknesses vary from a total of 760 m on the southeastern margin to 1600 m at Point Lepreau on the New Brunswick side, suggesting depositional thicknesses of at least 2000 m of Triassic sediments in the Bay.[21]

SURFICIAL GEOLOGY

Five main sedimentary units in the Bay of Fundy were recognized by Fader et.al.[12] as being; glacial debris, silt, sand, clay and sand and gravel units (Figure 2). The units covering the Triassic floor in the northern bay are the glacial debris (till) and Sambro sand and gravel. The till deposited by glaciers is composed of quartz and feldspars grains, rock fragments and dark minerals with striations and polished surfaces on larger casts attesting to glacial transport of the material.[22] Till thicknesses generally range from 18-37 m with a maximum of 73 m in old fluvial bedrock channels.[12] In the northeast section of the Bay, thick deposits of stratified glacial outwash overlie the unstratified tills.[32]

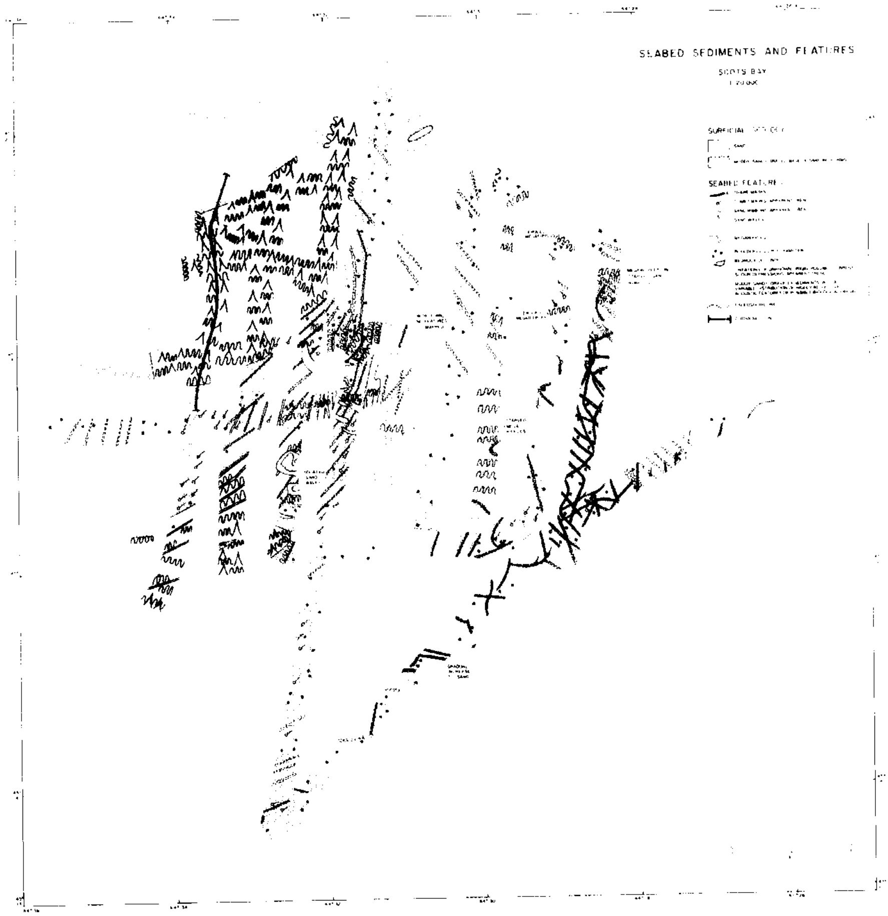

Figure 2. Surficial geology

GEOLOGICAL HISTORY

The lowest position of sea level prior to the Holocene transgression is critical to interpreting the distribution of the surficial sediments and their stratigraphic relationships within the Bay of Fundy. For the period 20,000 years B.P. to present, the amount of sea level lowering appears to have been about 120-125 m. Along the N.S. side of the Bay, the highest marine limit is 45 m above present sea level.[16]

Applying reasoning from Curray[7] and Milliman and Emery,[27] Fader[12] suggested a minimum isostatic rebound of 65 m for the south shore of the Bay. Grant[16] estimated that sea level fell to a position 20-30 m below its present level due to rapid isostatic rebound, thus transgression may have modified only the nearshore sediments of the Bay. The presence of large amounts of till on the floor of the Bay and the overlying angular to sub-angular material covering the till, suggest the till has not been transgressed and exposed to the high energy of a beach zone.

Tidal amplification commenced approximately 6,000 years B.P., accompanied by high tidal currents. Coupled with the increased hydrodynamic vigour and the shoaling bottom of the Bay, a change in sedimentation began. Modification of the surface till occurred, with the removal of the finer particles and a smoothing of the till profile due to infilling between local undulations with fine sand and gravel. Fine sands were redistributed and deposited over silt and clay pockets in some areas. Large areas of angular lag gravels developed and protected the underlying till from further erosion. Sand waves which have formed singly and in localized fields, range in height from a few to more than 18 metres.[15,12]

DATA BASE CONTROL

A grid system was established by running seismic lines along existing north-south and east-west Loran C lines at 0.75 km intervals. 100 KHz Klein side scan sonar data was collected along tracs 0.5 km apart, while simultaneously recording subsurface geological data using a Datasonics Bubble Pulser, an I.K.B. Seismic-boomer system and an Elac 30 KHz echo sounder. Compiled data was interpreted to define subsurface Quaternary stratigraphy. Eight Van Veen grab samples were taken to ground-truth these results and a bulk sample was taken to assess aggregate potential.[26]

DESCRIPTION OF SAND WAVE FIELD

The main sand wave field occurs at the mouth of Scots Bay approximately 1 km southwest of Cape Split and in water depths ranging from 22 to 37 m (Figure 2). The waves are sharp-crested with megaripples on their flanks (Figure 3). It appears that wavelengths range from 1 to 3 m. Generally, the sand waves increase in height from 1 m in the south to their maximum of 15 m. in the northern section. Adjacent to and extending farther south of the main sand wave field lies a broad patch of sand with a few sand waves, exhibiting superimposed megaripples. The highest sand wave is 3.5 m and the orientation of numerous sand ribbons suggests they have been formed by bottom currents moving from southwest to northeast. The regional current pattern with outgoing tides moving from the northeast has minimal effect on this depositional area due to the currents being deflected by the Cape Split promontory. A lag gravel surface (Figure 4) consisting of muddy, sandy gravel lies at the base of the sand wave field and crops out to the east and south of the field.

Internal structures noted on seismic reflection profiles within individual sand waves are interpreted as buried earlier generation sand waves, indicating growth of the field over time. When compared with previous data,[31] it appears the field may have migrated several hundred metres to the northwest. Recent and past fish trawl markings (Figure 5) proliferate the seabed southeast and west of the major sand deposit.[26]

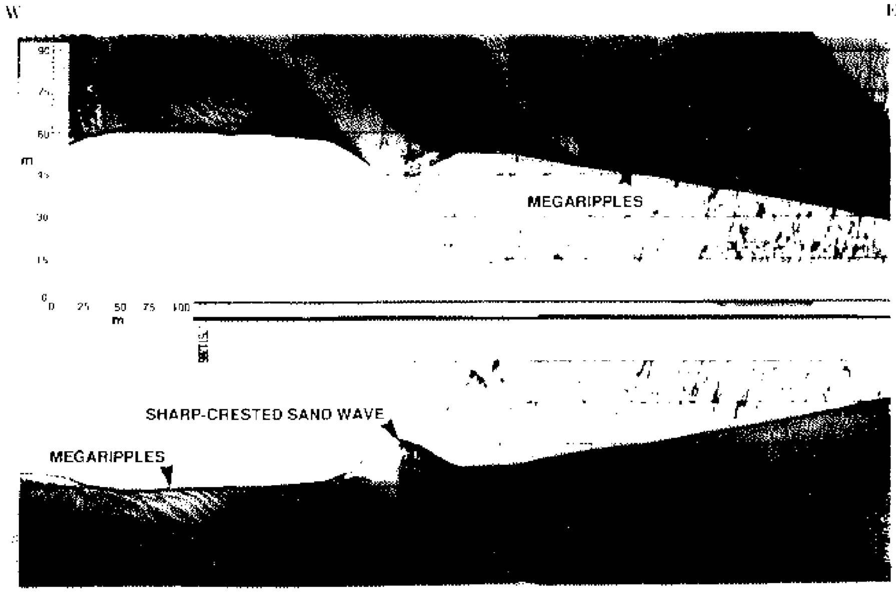

Figure 3. Sand Waves

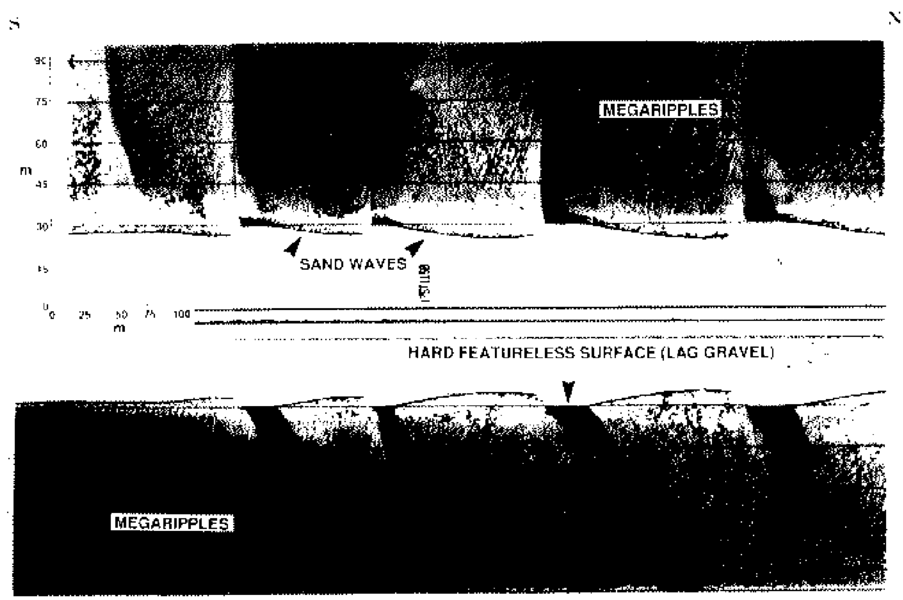

Figure 4. Lag gravel

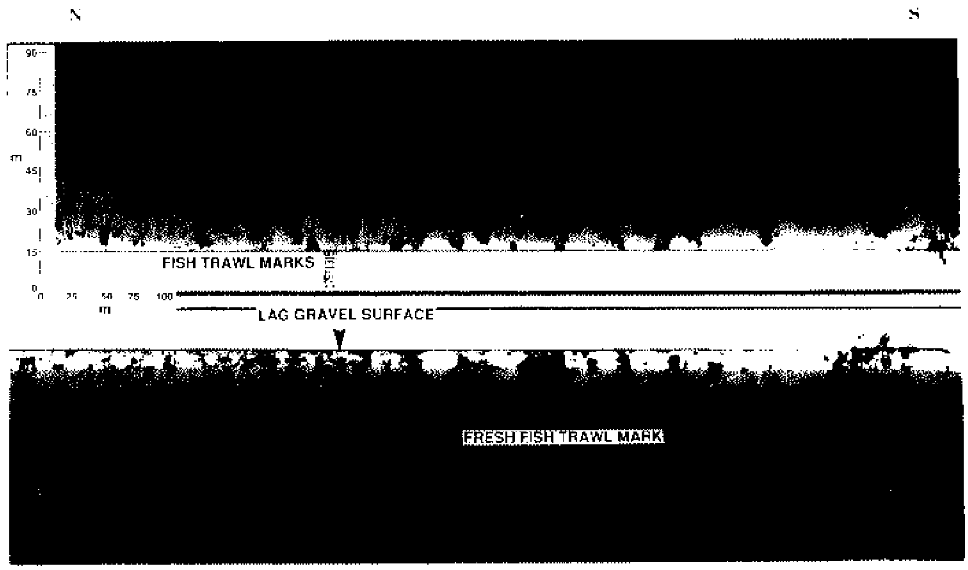

Figure 5. Trawl marks

The areal extent of the sand body was delineated from sonar and seismic data to be approximately 7,000,00 m^2. An average sand thickness of 5 m was assumed from reflection profiles and a volume of approximately 35,000,000 m^3 sand was established. Petrographic analysis of grab samples indicates the presence of 5% biolithic fragments dominated by sub- to well-rounded quartz fragments with secondary reddish, sandstone fragments, feldspars and a suite of metamorphics. Phi size analysis (Figure 6) indicated the sand percentage to be 97.3%, gravel as 1.0% and silt as 1.7%. Eight samples analyzed for heavy mineral content indicate a range of 0.70 to 4.43 percent heavies by weight contained in the gravel lag.[26] A bulk sample taken from the sand wave deposit awaits analysis.

ENVIRONMENTAL STRESS ASSOCIATED WITH MARINE MINING

Numerous studies have documented various potential deleterious and beneficial effects that may result from marine extraction of aggregates, contingent upon the working depths, currents, bottom configuration, surficial mix and type of equipment employed. Bottom dwelling organisms in the path of a dredge head will be destroyed, but if a layer of original substrate remains, the same type of organisms may return, either through migration or recolonization. Recolonization rates of one to five months have been reported by de Groat.[8] Turbidity plumes may cause the reduction of light available to surface plankton due to absorption by suspended particles and/or changes in the spectral composition, since particles scatter blue light more than red light.[9] Fish species sensitive to suspended sediment (eg. herring) will avoid the affected area.

Suspended material was reported to have adverse effects upon musssels close to the dredge and hinder the settlement of encrusting organisms near the dredge site.[19] Contrasting this, no adverse effects were observed on oyster larvae,[2] quahog clams[1,2] or lobsters, which are relatively tolerant to suspended sediment except while molting.[5] Aggregate operations avoid areas with a significant amount of fines and are not of continuous duration, thus impacts from a turbidity cloud are minimized. The effects are small relative to the overall marine coastal environment[10] and the material in suspension is quickly dispersed, thus exposure is of short duration.

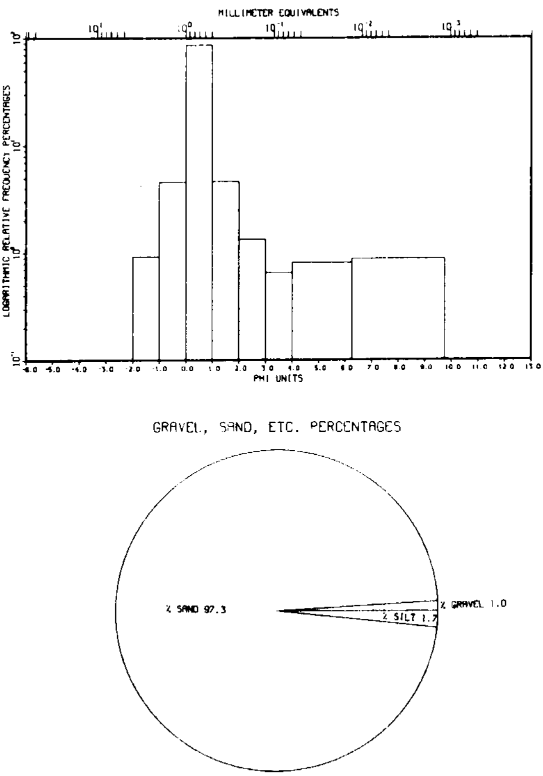

Figure 6. Sample grain size analysis

Motyka and Willis[28] found that coastal erosion increased when dredging occurred in water depths less than one-half the normal wave length or less than one-fifth the extreme of the waves. A minimum of 13 m has been recognized as a limit on English coastlines. Studies by Gillie and Kirk[13] and de Groot[8,9] suggest that holes or pits created by dredging seldom infill due to sediment transport. These pits have proven to hamper the use of bottom trawling gear, thus stationary suction drilling producing pits should be avoided in areas of bottom trawling, bottom scallop dredging or clam raking, especially if the material being excavated is discontinuous.

Furrows left by bottom suction dredges are normally only 20 to 30 cm deep and infill rapidly, posing minimal hazard to fishing gear. Since bottom dwelling fish tend to spawn[11] on gravel bottoms (eg. herring), removal of sand would create liittle disruption and would actually create a new potential spawning ground over the remaining lag gravels.

Heavy metal release from bottom sediments is a potential problem only where the contaminants have been injected into the substrate.[9,13] Nutrient release from disturbed sediments can create a temporary change in the local biomass and diversity and production of species.[9] Increased biomass could actually enlarge fish feeding grounds, thus potentially increasing the fish population.

Smothering off bottom dwelling organisms due to the settlement of suspended sediments and the associated depletion of oxygen in surrounding waters can be a problem where the ecosystem has an unusually high sensitivity (eg. coral reefs and sea grass).[3] Herbich and Schiller[17] reported that damage to shellfish from smothering was limited to within 400 m of the dredge. When mining well-sorted coarse sands and gravels smothering effects are minimal since little material is available for suspension.

Oxygen concentratioon in the water column can be reduced by suspended sediments that provide an increase in surface area available to bacteria[29] and hence an increased release of unoxidized biogenic material. This would present limited problems in suction dredging of sands where minor organic material is present and minimal material is thrown into suspension.

RECOMMENDED MARINE AGGREGATE EXTRACTION PROCESS

Trailing suction hopper dredges are effective for dredging laterally extensive medium to large sand and gravel deposits. They can operate in a variety of sea states and present a limited navigational hazard, but cannot be operated on an irregular seabed and recover materials to depths of only 20 to 30 cm per cycle. No water column turbidity plume is generated and resuspended sediment tends to remain in the lower water column near the sea floor. Water overflow at the ocean surface can result in a surface turbidity plume.[18]

The stationary suction dredge can anchor over a deposit and dredge continuously to depths of 80 m. A typical dredging operation will potentially produce pits of 10-100 m in diameter and 20 m in depth. The dredge head is embedded in the substrate, thus neither minor seabed turbidity, surface turbidity plumes, nor water column plumes are created. Unless the pits created by the dredging activity can be located immediately adjacent each other, a series of depressions will be dot the bottom which will normally only partially infill.[18]

CONCLUSIONS

A deflection of ocean currents by Cape Split has ensured that the major sand deposit at Scots Bay remains intact and has actually been enlarging. Heavy minerals associated with the gravel lag may provide additional economic incentive for resource development. Due to the smooth surface and continuity of the sand deposit and the uniform topography of the underlying gravel lag, a trailing suction hopper dredge may be employed effectively. Continuous sweeps could be performed over the deposit in a southerly to northerly direction skimming off approximately 2 to 3 cm of material on each pass. The extremely low amount of fines (1.7%), coupled with the use of the suction dredge, practically negates potential environmental damage during aggregate extraction. Increased nutrient loading over the expanded gravel bottom could lead to increased fish stocks.

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Multiple Use Compatibility: Commercial Fishing and Coastal Zone Development

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ABSTRACT

As the development of the coastal zones of the United States has proceeded, so the space available for commercial fishing operations has diminished. During the same period, the fishing industry has changed too, and non-traditional patterns of operations need different forms of access to the coastal zone. Finally, the growth of human activities and population in the coastal zone is affecting marine resource habitats and nursery areas, causing changes in local ecosystems which in turn affect the commercial fishing industry. These impacts are described using six case-studies developed by researchers in different states.

INTRODUCTION

The commercial fisheries of the United States have adapted and expanded in the past fifteen years. The passage of the Magnuson Fishery Conservation and Management Act (Magnuson Act) in 1976 created a fishery conservation zone two

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The views expressed in this paper are those of the author; they should not be construed as being the views of the National Marine Fisheries Service or National Oceanic and Atmospheric Administration.

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hundred miles in breadth around the United States and its territories.[a] The stated goals of fishery management were to conserve and wisely use the fish stocks within the fishery conservation or exclusive economic zone (EEZ) and to substitute American fisheries for those prosecuted by other nations within the U.S. EEZ. The second goal, that of Americanization of the fisheries, has been virtually achieved. The number of commercial fishermen increased by 58% between 1976 and 1988, from 173,610 to 273,700 persons. The overall number of commercial fishing craft declined 9.4% during the same period, from 102,621 to 92,900.[b] This apparent decline masks a major shift of investment within the industry. While the numbers of small boats declined by 19% to 69,600 craft in 1988, the number of larger vessels increased by 40% to 23,300. The improved technologies incorporated in the new and larger vessels also mask a further increase in fishing power. The units of effort represented by the 1988 fleet were an estimated four-fold increase over the units of effort employed in the United States fisheries in 1976.

From a fishing industry of relatively small vessels and small investments, has emerged an industry which now operates large fleets of factory-trawlers and other catcher-processor vessels. In 1990, for example, 70 factory-trawlers fished in the Alaskan groundfish fishery, in contrast to 1980 when one factory-trawler, the ARCTIC TRAWLER, processed 900 metric tons of cod.[c] The average length of these vessels was 231 feet, and their combined harvesting and processing capacity was estimated to be 2,336,000 metric tons annually. The average length of groundfish trawlers delivering to shore processors in 1990 was 82 feet, and the on-shore plants' processing capacity was estimated to be 635,700 metric tons. While the preponderance of the largest catcher-processor vessels fish the waters off Alaska, catcher-processor technology is found in nearly all the offshore fisheries of the United States.

The increased domestic harvests have not satisfied the public appetite for fish products. U.S. per capita consumption of commercially harvested fish and shellfish products has increased between 1976 and 1988 by 23% to 15.9 pounds. In 1989, the U.S. imported some 3.2 billion pounds of edible fish products while producing 6.2 billion pounds of domestically caught fish. However, for some highly valued species imported product dominates the market; 80% of shrimp eaten in the United States, for example, is imported.

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[a]The fishery conservation zone, extending outward from the territorial sea for two hundred miles, measured from the territorial sea baseline, was subsumed into the exclusive economic zone (EEZ) proclaimed by President Reagan (Presidential Proclamation No. 5030, March 10, 1983).

[b]The statistics on craft and employment are derived from: U.S. Department of Commerce (1990): Fisheries of the United States,1989; Washington, DC: U.S. Department of Commerce, National Marine Fisheries Service.

[c]Information concerning the Alaskan groundfish fishery is drawn from North Pacific Seafood Coalition (1990) and Dayton L. Alverson (1989).

In parallel with the small farming operations of the United States, the small fishing operations enshrined in the public stereotypes of the fishing industry[d] are now struggling to remain economically viable. The harvest per unit of effort expended has decreased significantly as fish stocks have declined in many fisheries; much of this decline is due to overfishing, but some of it is due to changes in stock abundance related to loss of wetland and estuarine habitat areas. Additional costs have been incurred as the industry has lost the use of port and staging areas to competing users. Coastal zone development is a major source of the increased costs and decreased profits of the traditional fisheries.

EFFECTS OF CHANGES IN PORT LAND USE PATTERNS

Gale[3] suggested that there are eight major types of communities, based upon their economic activities. In a discussion of rural coastal communities he suggests that two trends are paramount in forcing land use changes which affect the fishing industry. These trends are "gentrification" and the "growth machine." In Gale's analysis, "the gentrification process emphasizes the geographical mobility of capital, and the consequences of the invasion of residential and business capital upon existing, less powerful, residents and businesses." The "growth machine" process is focussed on the "typically small, property-owning segment, of the community likely to derive a direct financial benefit from community growth." Both processes exist in the studies of the southern California and Florida Keys communities discussed below.

Johnson and Metzger[5] and Meltzoff[7] describe changes that have occurred in port land use in southern California and the Florida Keys respectively. In both studies, recreational activities have taken over land and water space originally available to commercial fishermen. "The waterfront, leisure-styled residences, the yacht clubs and the marinas, the harbor-view restaurants and hostelries economically preempt the wharves and fish landings, the commercial boat yards and related marine industrial businesses."[5]

As coastal development has taken place, the fishermen have lost their ability to influence local planning decisions as newcomers, often retirees, move into their communities. As Meltzoff notes, "commercial fishermen define themselves as working class in relation to recreational fishermen and second-home[owners]/retirees."[7] This self-definition reflects the perceived ability of retirees and sportfishermen in the Keys to "gain access to and influence the political system."

[d]An example of the perpetuation of the stereotype is the use in advertisements for frozen fish products of pictures of small-scale fishing operations; it is considered unlikely that the fishermen shown in the advertisements supplied the product being marketed.

In both California and Florida disputes over land-use planning occurred over time. Newport, California was noted by Johnson and Metzger to have struggled with the incorporation of recreationally-oriented communities in 1919. Arguments over land-use planning in the Florida Keys emerged in the 1960s and the fishermen organized themselves in 1967 into the Offshore Fishermen of Florida in order to more effectively counter-balance the influence of developers and recreational interests at the State House. In both areas major environmental issues were masked by the debate over waterfront use. The development of residential communities and recreational facilities close to the water led to extensive bulkheading, landfilling, and dredging activities thus altering existing wetlands and estuarine habitat. Leakage from septic tanks, outboard motor use, and increased traffic through estuarine waterways further degraded the habitat available for fish and shellfish stocks.

For the commercial fishermen in California's "play-full" harbors, described by Johnson and Metzger, the response to the changes was to move to other less expensive, though less convenient, areas. Eventually, the commercial fishing activities in the area were confined to small sectors of estuaries, and the smaller operators either left the fishery or moved northward to areas with less recreational use. The small-scale fishermen in the Keys lost their right to operate from their backyards, by fiat of the Monroe County Land Use Plan of 1986, and their activities were confined to 40 "commercial fishing development areas" either co-located with existing processing facilities or in marginal areas far from "in-comer" neighbors.

Again the choice of these areas was not that of the fishermen; the added costs of moving boats and gear to new areas,and development of storage and dock facilities, benefitted only fish house owners and developers and imposed new cost factors for small operators. In particular, the commercial fishing development areas have restricted the ability of fishermen to competitively market their product. In the past fishermen were able to sell their fish to any one of probably three or four nearby processors; the co-location of dock areas with a processor in the commercial fishing development areas effectively ties thef ishermen to that processor. In cases where the processor also owns the land designated for the commercial fishing development area, Meltzoff reports that the fisherman is in double jeopardy. Sales to the processor are required if the fisherman is to keep dock and gear storage space, and the fisherman has no power to prevent the processor from selling the land. According to Meltzoff (personal communication; 1990), at least two, and possibly three, commercial fishing development areas have been purchased from processors by developers for conversion to recreational boating marinas.

CHANGES IN PORT LAND USE RELATED TO THE "NEW" FISHERIES

The development of catcher-processor fleets is a recent development in United States fisheries. Catcher-processor vessels have been used in the North Atlantic fisheries since the1950s by the United Kingdom, Germany, Poland and the

U.S.S.R., and in the North Pacific since 1962. At the time of the passage of the Magnuson Act, these four countries had been joined by Cuba, Japan, Eire, Spain, Italy, Romania, Bulgaria, Iceland and Norway in the deployment of catcher-processor vessels in the U.S. EEZ. The development of the United States fleet began in the late 1970s and by 1990 some 90 catcher-processor vessels had entered the North Pacific fisheries with another 60 vessels on order or under construction.[e] The conversion of oil-rig supply vessels to catcher-processors in the early phases of fleet development has been replaced by purpose-built vessels. The vessels are involved primarily in the Bering Sea and Gulf of Alaska groundfish fisheries, either trawling for pollock and Pacific cod or longlining for Pacific cod and sablefish. The Pacific coast whiting stocks are also of interest to the factory-trawler fleet. Capacity has grown to the extent that the catcher-processor vessels in 1990 were potentially able to harvest and process twice the amount of the entire Bering Sea and Gulf of Alaska pollock allowable harvests of 1.2 million metric tons.

The catcher-processor vessels need port facilities more akin to standard cargo ships. The size of the vessels, averaging 231 feet in length in the Alaskan fisheries, is such that deep-water dockage is required. The product off-loaded is already packed for shipment to wholesalers or secondary processors, so the facilities required by fresh-fish landings to primary processors are not necessary. Finally, support services for gear and vessel maintenance are typically provided by specialist companies rather than being done by the fishermen themselves.

The result of these changes, documented for the North Pacific Fishery Management Council by Dr. John Petterson of Impact Assessment, Inc. (IAI) — in social impact assessment profiles of four Alaskan fishing communities and Bellingham, Washington and Newport, Oregon — are shifts in port land use from dockage related to processing of fish to "full-service vessel supply and repair facilities."[4] These docks, modelled on those developed in Aberdeen and the Shetlands for North Sea oil-rig servicing, provide cargo handling space, space for gear storage, and warehouses and workshops for use by equipment supply and repair contractors. Facilities of this type have been developed in Sand Point and Unalaska, Alaska. The catcher-processor fleet's products are usually re-processed away from the port of landing. The IAI study found that fish product from catcher-processors based in Seattle was re-processed by plants in Bellingham, WA and in the mid-West where the costs were lower.

As these fleets develop, the traditional fishing ports will continue to focus on the fresh fish markets, but their share of the harvest will decline. Unlike the small-scale fisheries of the past which operate in a seasonal round of harvests of several species, the catcher-processor fleets are very specialized in both harvesting technology and processing technology. Vessels with a surimi product line, for example, need firm-fleshed species such as pollock to operate efficiently. These vessels compensate for their specialization by their mobility, and after fishing a

[e]70 of the active vessels were trawlers and 20 were longliners; see Dayton L. Alverson (1989) and North Pacific Seafood Coalition (1990).

stock to its limits ("pulse-fishing") they move to another area. The small-scale fishermen are restricted geographically, and compensate for this by fishing a seasonal round of fisheries. The catcher-processors have the capability of outfishing the small fishermen, thus truncating local seasonal rounds and reducing the supply of fresh fish moving through the small ports.

In a study of Plymouth, Massachusetts, Susan Peterson and David Terkla examined the debate over rebuilding the town's commercial fishing dock.[10] They showed that the economic returns from the local fishing fleet did not justify the investment in the dock, unless it was viewed "as more important than other major industries to the town's image and. a major tourist attraction."[10] The availability of locally caught fish for restaurant and retail sales plus the ambience of an active fishing fleet, combined with the year-round employment generated directly by the fishery, were seen by Plymouth as adequate justifications for continuance of the town's support of commercial fishing activities, but not necessarily for rebuilding the dock. In large measure this is because the fishing industry, with only 81 vessels based in Plymouth, does not have the scale of employment necessary to convince voters to expend the funds needed to repair the dock. The economic multipliers suggested by Peterson and Terkla for the fishing activity are of the order of 1.6 and less than those in the tourist industry. The future of the New England groundfish fishery is problematic; the landings are 20% of the levels in 1960, while the number of vessels has increased. For these reasons, Peterson and Terkla point out, banks are unwilling to finance small-scale fishing industry expansion or improvements.

These changes within the fishing industry will have impacts on the use of land within fishing communities and in port and dock areas. At this point it is too early to determine the extent of the changes that will occur, particularly since the catcher-processor fisheries appear to be heavily overcapitalized at this time. Nor is it possible to predict the outcome of thelimited access schemes for the fisheries being proposed by the Regional Fishery Management Councils; these limited access schemes may stabilize domestic fisheries and provide a new lease on life for small-scale fishing operations.

COASTAL ZONE DEVELOPMENT AND ENVIRONMENTAL CHANGES

In our discussion of the shifts in use of harbor and estuary space it was noted that environmental factors, particularly loss of fish habitat and pollution, were impacting the fishing industry. Changes to the coastal environment, including drainage and bulkheading of wetlands, diversion of freshwater flows, conversion of upland areas from forest or field to urban settlements, and intense use of water space, disrupt the delicate balance of salinities, temperatures, and vegetation necessary to support fish and shellfish populations. It is estimated that 96% of the commercial fish and shellfish species and 70% of the recreationally-sought species of fish in the southeastern United States are estuarine dependent at some point in their life-cycle. In this same area, the states of North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, and Louisiana lost 1,312,000 acres of wetlands, or 7% of the national total, in the twenty years prior to 1976. In the first six states, wetlands loss is due primarily to urban development. The annual loss of wetlands in Louisiana, approaching 35,000 acres per year, is due mainly to flooding as wetlands erode and submerge after loss of protective cover and the dredging of channels to support oil industry activities.

California has filled, and lost, some 90% of its historic wetlands and a similar proportion of the habitat for its salmon fisheries. In California in particular, and the Pacific Northwest in general, diversion of freshwater flows for irrigation, household supply, and power generation activities have damaged anadromous fish stocks, including salmon, and severely curtailed historic fisheries.

James Nance and Nina Garfield studied the effects of the "Texas closure" on the shrimp fishermen of Galveston Bay and southern Louisiana.[8] The Texas closure of the shrimp fishery, from June 1 to July 15 each year, allows junvenile shrimp to move out of estuarine waters into the open sea and to grow into a larger, more valuable animal before harvesting. The State of Texas has implemented the closure in state waters since 1959; the Gulf of Mexico Fishery Management Council and NMFS extended the closure to the EEZ off Texas in 1981. This measure thus, in part, compensates for any decline in numbers of shrimp due to loss of wetland and estuarine habitats.

The study findings were that the Texas shrimpers benefited from the closure in terms of ex-vessel values of landed shrimp. However, the study also showed that shrimping effort and employment *increased* in times of economic decline. This was attributed by the authors to coastal populations turning to fishing when other economic activities were not available. In the case of Louisiana, Nance and Garfield suggest that the decline of the offshore oil industry and the attendant unemployment caused younger, unskilled men to enter the fishery. Thus the coastal area most degraded through wetland loss is also the focus of increased fishing effort when economic times are bad.

The decline in the population of red drum in the Gulf of Mexico, due to a combination of overfishing and loss of inshore habitats, caused recreational fishermen to seek game-fish designation for the red drum, or redfish, and the banning of commercial fishing on the stock. First enacted in Texas in 1981, the ban was soon being considered by legislators around the Gulf of Mexico. In Florida, Linda Lampl described the social and economic impacts of the closure of the commercial red drum fishery and reduced catches in the shrimp fishery for the 400 people employed in the fishing industry of Pine Island, Florida.[6] The loss of elements, such as red drum, of the seasonal cycle of fisheries exploited by Pine Island fishermen impacted all fishermen. It resulted in lower incomes, periods of minimal employment, and greater pressure on the fisheries remaining open to the commercial fishermen.

SUMMARY

The three issues outlined above — loss of harbor space, changes in land-use needs, and habitat degradation — are issues which are normally considered to be "only" fishing industry, or "only" land-use zoning, or "only" environmental "problems." However, they interlock throughout the coastal zone in the same way that the tide washes through estuaries and links the land and sea. Changes caused by human activities also wash through the human environment causing ecological, economic, and social impacts.

These impacts need careful assessment and consideration. Often, the "will" of the "majority" — focused on a special issue or activity — may be imposed without an understanding of the impacts on the "minority" and other activities. The characteristics, of versatility and small numbers, of small-scale fishermen that lead to a "good fit" with the natural system weigh against them when dealing with the political system of majority rule and competitors for the scarce resources they utilize.[6] As we consider and develop "coastal ocean" programs and "Coastal America" initiatives, it behooves us to consider the ecological, economic, and social impacts of these programs and projects; attention to achieving a "good fit" will benefit all concerned with coastal ocean space utilization.

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Resolving Conflicts Between Commercial Fishing and Offshore Oil: The Local Marine Fisheries Impact Program

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ABSTRACT

Two of the most highly visible existing economic uses of ocean space are commercial fishing and offshore oil and gas operations. Particularly in areas with a narrow continental shelf, there is also a high potential for conflicts both at sea and in port. There have been several efforts to resolve these conflicts in California. Specific measures have been negotiated between the state and federal government as lease sale stipulations. Mitigation measures have been applied through the consistency review process and as project permit conditions. Industry-to-industry negotiations through the Joint Fisheries/Oil Liaison Committee have also produced various approaches to reduce physical conflicts.

These efforts still left unresolved the question of economic impacts. After failing to negotiate a solution to this issue, the Liaison Committee approached the state with a proposal which was subsequently funded through revenues California receives from oil and gas activities in federal waters (the "8(g)" funds). Now in its final year, the program is a broad-based effort involving alternative gear research to reduce conflicts with oil facilities, safety grants to enable fishing operations to move further offshore away from oil activities, development of port facilities, identification and removal of seafloor debris, market and population research for new fisheries, and creation of a seafood marketing council as a permanent vehicle for the fishing industry to continue successful program activities. Operation of the program has continued the consensus approach of the Liaison Committee, with guidance from a committee of commercial fishermen and advisors from agencies, academia, and the oil industry.

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INTRODUCTION

Multiple use conflicts are a fact of life. When two or more user groups want to be in the same place at the same time, typically at least one has to move out of the way, and the ones that do feel impacted.

The incidence of these impacts has not always been high in the use of ocean space. Multiple use conflicts have been more pronounced in the case of onshore resources and are increasing for coastal resources, but commercial use of the ocean has been similar to the aura of the adventurer facing the unknown challenges of the open seas.

This situation is changing. The pressures of coastal uses have extended into adjacent seas. The concept of wilderness protection has been applied through marine sanctuaries and other protected zones. Commercial and recreational uses are constantly expanding through new technology, shifting market conditions, and the ever-present challenge of testing the last frontier. As uses of ocean space expand, so will the probability of conflict between those uses.

Oil and gas and commercial fishing are currently the two largest commercial users of ocean space. Interactions between these two industries demonstrate the range of conflicts that can be expected from other emerging uses such as mining, floating structures, and non-oil energy development. Similarly, the interactions of these two industries with yet another large user group — recreation — further illustrate the types of conflicts that can occur as pressures build on the allocation of ocean space.

All three activities have a long history in California. Offshore oil and gas has existed in some form since 1898, beginning first with drilling from piers and continuing on platforms starting in 1954. Fishing, similarly, has been a major industry throughout the state's history. Though the heydays of the industry are often associated with the sardine fishery that collapsed in the 1960s, fishing continues to be a mainstay of local economies in many parts of northern and central California.

The range of conflicts between fishing and oil have been detailed in several sources.[1,2,3,4,5,8,12,15] Specific conflicts vary considerably by location, the level of the two activities, as well as by type of gear used by the affected fishing fleets. For instance, drag fisheries present the most conflicts with permanent facilities such as pipelines and platforms. Set gear fisheries have more conflicts with associated activities such as boat traffic and seismic surveys. In general, however, these conflicts fall under the following general categories.

Resource conflicts can occur if there are impacts on the fishery resource or if access to the resource becomes limited. Issues raised by fishermen include potential damage to eggs and larvae from seismic survey signals; the possible effect of these signals in causing fish to disperse or go off the bite; effects of blasting used at the abandonment stage to remove facilities; the effects of drilling discharges such as produced waters, muds and cuttings; and the potential effects of oil spills on fish and shellfish quality and reproduction. Preclusion can occur either temporarily in the case of exploratory drilling and seismic surveys, or permanently for some gear types as permanent production facilities are installed. Preclusion exists both from the actual facilities and, as is the case for some California platforms, safety zones that prohibit boats over a certain size.

At-sea conflicts occur from interactions between the two operations. Nets have been snagged and damaged by sea floor debris, anchor scars, and protrusions on platforms and pipelines. Set gear has been lost through damage by crew and supply boat traffic and seismic survey runs. On the other side, seismic survey runs can be interrupted if fishing gear is not removed from noticed operation areas.

Harbor conflicts arise from competition for space and support services. Fishermen have experienced increased delays for fueling when crew and supply boat traffic increases in a port. Docking space and onshore work areas can be reduced as oil and gas operations compete for the limited available space. Oil and gas vessels and drilling rigs are sometimes forced to anchor outside crowded harbors, further reducing access to fishing grounds in those areas.

Economic conflicts can stem from any of the above sources, but generally arise from increased operating constraints on fishing as oil and gas activities expand in the offshore areas. Fishing time can increase as greater care must be taken to avoid oil and gas facilities and related sea floor obstructions. Operating costs and product quality can be affected due to longer travel times to new fishing grounds away from oil and gas operations, exploration efforts needed to locate new grounds, or greater competition for the same labor pool. Capital costs can increase if gear types must be modified to avoid the conflicts. Economic effects can also percolate through the local economy if product is not available to local handlers and processors, or harbor conflicts also result in loss of space for unloading and sales.

In many respects, the two industries also share common ground. Fuel is a major component of fishermen's operating costs, and adequate supplies of oil that can maintain stable prices serve the interests of the fishing industry. Both industries are resource dependent and exhibit cyclical behavior. In areas such as the Gulf of Mexico, the effect of these cycles have been moderated to some extent by movement of labor between the two industries. Oil and gas facilities can also provide increased habitat through artificial reefs, which can increase local fishing opportunities if access is permitted. Finally, both industries share some common conflicts with other ocean uses, primarily recreation. In this respect, both industries represent common competitors for the resources needed by recreational and tourism uses: e.g., commercial fishing vs. recreational fishing, open ocean views vs. views of platforms, harbor facilities for industrial and fish cleaning operations vs. harbor locations for restaurants and shops, and docking space for industrial boats vs. docking space for recreational marinas. In all cases, the industrial uses face increasing pressures from recreational demands that increase along with coastal populations.

The common ground can outweigh the conflicts if there is enough room. Offshore oil and fishing industries have had far fewer conflicts in the Gulf of Mexico, where there is greater symbiosis between the two. In California, the constraints have been greater, and competition for ocean space has resulted in a greater incidence of conflicts.

First, the continental shelf off California is extremely narrow and in some areas almost non-existent. Fishing and oil are limited to the same relatively small area; whereas, in the Gulf, the shelf extends out well beyond 100 miles. The California fishing industry in areas adjacent to offshore oil production consists of nearshore fleets for the most part, and these have less flexibility in extending their range either through longer travel times or through staying at sea longer and fishing more intensively in a given area.

Second, the potential benefits from oil and gas are not as important to California fleets. Unlike the Gulf, substantial hard bottom areas are already present, and the benefits from artificial reefs are fewer, particularly when existing hard bottom is damaged or precluded by oil facilities. Fewer opportunities exist for labor movement between the two industries, as major oil and gas centers located nearby in southern California and Kern County can provide a ready supply of labor and services. The importance of labor mobility is further diminished by the fact that on a relative basis, the two industries comprise a smaller portion of the overall California economy. Labor mobility, therefore, is not focused on the two industries, and is more likely to encompass other sectors.

Third, the constraints set by the prior two factors provide less room for negotiation, particularly in light of competition from adjacent urban uses, recreation, and ocean protection zones. When the two industries bump up against each other, the options for one to simply move to a new area are much more limited. From this perspective, the inter-industry conflicts must be viewed not only in terms of the direct impacts, but also in terms of the effects they have through intensifying problems with other uses.

Finally, the severity of the conflicts has been set in many cases by outside, cumulative factors that have further tightened the constraints. Offshore oil and gas up to the 1960s proceeded at a relatively slow pace, and new facilities stopped altogether following the 1969 Santa Barbara oil spill. Competition from oil and gas subsequently lessened, but commercial fishing experienced new pressures from elsewhere. Fuel and insurance costs increased substantially. Revenues decreased as a result of El Niño and competition from increasing imports. The local fishing industry was therefore in a significantly weakened position when new conflicts started with a dramatic increase in offshore oil and gas activities in the 1980's. The conflicts from these new activities further weakened the economics of the local fishing industry, and came at a time when they could least be absorbed.

CONFLICT RESOLUTION

Multiple use conflict resolution can take any one of several forms, but generally these fall under one of three headings. Avoidance seeks to remove the source of conflict, and works best when there is adequate space in which to maneuver. Mitigation modifies specific operations or provides additional control measures that can reduce the actual effects of a given conflict. Compensation accepts the conflict or the mitigated but residual conflict, and provides cash payments, off-site resource access, or other benefits in an attempt to balance out any negative impacts. All of these have been applied in one form or another to the oil/fishery conflicts. Hildreth[8] provides a more detailed typology of resolution approaches which, with a few additions, provides a useful guide to these different techniques.

Ocean Use Priorities

Current California statutes contain no overall priority list of ocean uses that could be applied to decide whether specific ocean spaces should be devoted to oil and gas or to fisheries. The basic policy guideline in approaching use conflicts is to "Assess the long-term values and benefits of the conservation and development of ocean resources and uses with the objective of restoring or maintaining the health of the ocean ecosystem and ensuring the proper management of renewable and nonrenewable resources" [California Public Resources Code, section 36002.(a)(1)]. The California Coastal Act [California Public Resources Code, section 30000 et seq.], however, does establish among the priority uses within the coastal zone protection of commercial fishing facilities and siting of coastal-dependent energy facilities. Though not statutory requirements, the California Coastal Commission has also adopted general policy guidelines for how use conflicts between the two industries should be resolved.[3] This approach of prioritized uses by itself has not removed specific conflicts, but has provided a framework for how the issues are handled through some of the processes discussed below.

Ocean Planning/Zoning

Led by such states as Oregon, ocean planning and application of land use zoning techniques have begun to be used as a means to segregate incompatible ocean uses. California currently has no such comprehensive ocean plan. However, the state has historically maintained very active ocean management programs, and individual agencies have implemented single purpose plans and established various types of "zoning" tools. Both permanent and temporary oil and gas sanctuaries preclude offshore oil and gas activities throughout much of the state. Commercial fishing activities similarly are regulated according to various zones in state waters that set forth allowable and prohibited fishing activities. The state's water quality Ocean Plan designates areas of special biological significance with no-discharge standards, and establishes water quality criteria in other areas based on designated beneficial uses such as fishing. Underwater parks also specify allowable activities in certain ocean areas.

Taken together, these individual designations have produced a de facto ocean planning framework which has served in some cases to avoid fishing/oil conflicts. This existing structure is currently being evaluated through the California Ocean

Resources Management Program under the Secretary of Environmental Protection. The purpose of this Program is to develop recommendations for improving the State's ocean management capabilities — including, if warranted, recommendations for developing a single ocean plan — protecting the state's interests as they are affected by federal ocean management programs, and exploring options for cooperative state/federal management.

The existing ocean planning and zoning procedures in California have served to focus many of the conflicts to specific areas, and have also been applied to resolve certain resource and economic conflicts. However, both industries view the existing procedures as both helping and harming their interests; e.g., an oil and gas sanctuary may leave an area open for fishing, but access may be limited by prohibitions on specific gear types or commercial fishing altogether. These procedures also generally apply only to state waters, and do not provide a means to resolve conflicts extending to federal waters.

Conflict Avoidance

Additional avoidance techniques have been applied on both macro and micro scales. Delaying the conflicts has been pursued directly through support of congressional leasing moratoria, and has occurred indirectly as exploration and production declined in the 1980s due to falling oil prices and permitting delays. Using the Outer Continental Shelf (OCS) Lands Act section 18 and 19 process, California has also negotiated deletion of specific tracts and wider areas based in part or in whole on the need to protect fisheries resources. Project specific avoidance measures have included siting facilities to avoid sensitive resource areas such as hard bottom. Operational measures have included scheduling construction or exploration outside of high-conflict fishing seasons, and the notification procedures and vessel traffic corridors of the Liaison Committee discussed below. The avoidance approach can be successful in resolving resource, at-sea, and economic conflicts in both state and federal waters; and it has been applied to resolving existing conflicts as well as preventing future conflicts associated with new facilities.

Risk Analysis to Establish Buffer Zones

This approach has been used to establish buffer zones around some federal platforms off California. Vessels over a certain size are prohibited within the zone, primarily as a safety measure to prevent collisions. This measure has produced an increase in the areas precluded from fishing operations, and generally the approach has had only limited applications to address fishing/oil conflicts.

Memorandum of Agreement

In Lease Sale 73, California negotiated an MOA to provide additional measures addressing fishing/oil conflicts. The MOA covered tract deletions, as well as a series of lease stipulations and notices to lessees that specified baseline measures to reduce fishing/oil conflicts along with a number of other environmental protections. The measures included use of jack-up rigs to minimize space conflicts during exploration, notification procedures to fishermen prior to commencing oil and gas operations, review of exploration and development plans by commercial fishermen, procedures to prevent subsea obstacles from debris, evaluations of onshore impacts from harbor conflicts, specification of crew and supply boat routes, analyses of specific conflicts and impacts on commercial fishing and the fishery resource, and procedures for ongoing consultation to minimize future conflicts. The MOA approach provides a means to ensure conflicts will be addressed in federal waters, but generally can be applied only to future resource and at-sea conflicts.

Mediation

The primary fisheries mediation effort in California has been through the Joint Oil/Fisheries Liaison Committee.[5,6,12,15] Begun in 1983 largely through the efforts of the local Sea Grant Marine Advisor, the committee currently consists of four fishermen elected from the industry in the Santa Barbara Channel/Santa Maria Basin area, and four representatives of the offshore oil and gas industry. An additional fisherman and representative of the seismic survey industry also sit on the committee to help resolve issues specific to those activities. The committee has primarily been successful in negotiating measures to reduce space conflicts. These measures include: (1) notification procedures to minimize occasions when the two industries will be operating in the same area; (2) establishment of vessel traffic corridors to ensure set gear inside the 30–fathom line will not be affected by oil and gas traffic; (3) development of guidelines to minimize conflicts from seismic surveys, which were later adopted by the State for renewal of geophysical and geological permits; (4) creation of a geophysical manual to familiarize both industries with each other's operational constraints and thereby reduce conflicts; and (5) ongoing case-by-case mediation by the committee's Liaison Officer. The committee has also sponsored several research efforts to help clarify the incidence of resource impacts, including effects of seismic survey signals on fish behavior and on eggs and larvae. The mediation approach has enabled the two industries to develop measures applied to both resolving existing and preventing future conflicts. The liaison process has been more effective in addressing the at-sea and harbor conflicts that involve working out space-sharing procedures, and somewhat successful in resolving some questions related to resource conflicts such as the studies referenced above. The mediation process has not been able to resolve the economic conflicts, as discussed in the next section.

Task Forces/Joint Review Panels

This approach attempts to address multiple use or jurisdictional conflicts through cooperative study or decision making efforts. Such an approach is being used in the Pacific Northwest, wherein the U.S. Department of the Interior, Oregon, and Washington have identified a series of studies that will be required prior to any lease sale in the area. Several of these studies include evaluating the potential impacts on the local fishing industry, and will serve as a common information base for Interior's leasing decisions and the states' review of those proposals.

Comparable efforts have taken place in California for production projects through Joint Review Panels. Composed of the primary state, local, and federal permitting agencies, these panels have prepared joint environmental impact studies[1,2] that have identified the full range of potential impacts along with specific avoidance and mitigation measures. This approach has been used to help ensure that each individual agency considers both onshore and offshore impacts in their decisions, and that a common set of mitigations are established.[9] This approach has been used to work out on a cooperative basis measures to resolve future resource, at-sea, harbor, and economic conflicts from new oil development in both federal and State waters. The measures, however, have been applied primarily on a project-by-project basis.

CZMA Consistency

In addition to the section 18 and 19 provisions of the OCS Lands Act, states also review federal leasing, exploration, and development proposals under the consistency provisions of the Coastal Zone Management Act. As applied by the Coastal Commission pursuant to their commercial fishing policy guidelines, the consistency process has been used to modify projects to incorporate specific avoidance and mitigation measures. Many of these have been identified through the Commission's participation on the joint review panels discussed above. This approach has been used to reduce future resource conflicts through such means as limitations/preventive measures related to drilling discharges and through scheduling of activities to avoid specific fishing seasons; at–sea conflicts through debris avoidance provisions; and economic conflicts through the compensation procedures discussed below. The consistency authority also provides a direct means to apply these state provisions to federal waters.

Permit Conditions

Conditions have been imposed by state and local agencies through their permitting and other approval authorities on onshore facilities, pipelines, and other offshore structures. The conditions can address avoidance, mitigation, and compensation measures such as: notification requirements; contributions to mitigation funds; avoidance of debris creation; employee educational programs to make them aware of how their activities may create conflicts; contribution to resource enhancement funds; use of specific vessel traffic corridors; operational limitations to reduce conflicts such as those created by anchor scarring; and seasonal limitations to avoid prime fishing activities.[15] This approach can be used to address the full range of conflicts, but generally is limited to addressing future rather than existing conflicts. Through their permitting authority on ancillary facilities, state and local agencies have been able to apply these measures in both state and federal waters.

Compensation

Compensation has occurred on both industry and individual levels. Pursuant to the OCS Lands Act, the Department of Interior maintains a contingency fund to compensate fishermen for gear loss related to oil and gas facilities or activities where a specific company is not clearly at fault. This fund has had limited success due to the complexity of the application process, the proof required of fishermen to establish that losses were due to oil and gas, and the long delay times between application and payment of a claim. The County of Santa Barbara has maintained a Local Fishermen's Contingency Fund supported by oil industry contributions made pursuant to project permit conditions. This fund provides a revolving loan pool to fishermen with claims to the federal fund, and makes payment where federal claims have been rejected. The same funding source was used by the county to create a Fisheries Enhancement Fund which, although relatively small in size, supports a variety of enhancement projects such as harbor facilities, marketing assistance, and resource development. Santa Barbara and other coastal counties have funded similar enhancement/mitigation projects through grants received from the state, which are funded through California's OCS Lands Act section 8(g) funds.[16]

Direct payments have also been made by companies to individual fishermen. This approach, while addressing individual impacts, has engendered considerable controversy. From the commercial fishing industry standpoint, this approach does not address downstream industry impacts, such as those caused by loss of local product to handlers and restaurants. Payments can also be disruptive to local fleets, based on who receives/takes the compensation vs. those that do not. From a policy standpoint, direct payments have immediate implications in a number of areas. Fisheries are a public resource and are not "owned" by individual fishermen, and it is the public as a whole that suffers the loss for any damage to the resource. To the extent the compensation serves as payment for loss of access to the resource, the approach also runs the risk of setting precedent for fishery management measures that similarly limit access through size limits, gear restrictions, seasonal closures, and catch quotas.

Compensation has been used as a means to help address a range of conflicts that have occurred in both state and federal waters. These measures have not specifically removed the conflicts, and their application has in some cases caused further controversy.

LOCAL MARINE FISHERIES IMPACT PROGRAM

The Local Marine Fisheries Impact Program grew out of the negotiation process of the Liaison Committee discussed above. As indicated, the Liaison effort has been fairly successful in addressing space use conflicts, but the question of economic impacts has not been as amenable to solution. The committee had consciously taken a cautious approach to this question, dealing first with other issues that could be handled with less of an economic cost to either industry. As the integrity of the negotiations held up with these initial issues, the committee next turned its attention to the economic losses which the fishermen had long intended to address since the beginning of the mediation effort.

Mediation failed on two points. First, the committee could not agree on a methodology to estimate the economic impacts, and in fact, a totally objective methodology may not exist. Prior methods used in environmental impact analyses[1,2] are based on fairly simplistic assumptions. In essence, ocean areas precluded for the affected gear types are determined. An average fish catch per acre is then applied and used to estimate the economic value of foregone harvest. The base losses then are sometimes entered into economic base or input/output models to calculate downstream impacts in the local economy. This approach suffers from unrealistic economic and biologic assumptions (e.g., fish exist uniformly over the affected area and do not move; fishermen are not able to move to other areas; fish ticket data are accurate), and does not fully account for economic losses due to many of the conflicts discussed earlier in this paper (e.g., increased fuel costs, greater risk caused by longer fishing trips, harbor conflicts). The committee did commission an initial economic study which largely proved inconclusive and which would have required significant added costs to arrive at a more refined — but still likely debatable — figure. The committee felt these additional study costs would be better applied to measures that could more directly benefit fishermen.

Second, the oil industry and federal government were hesitant to offer up compensation, particularly for past or existing economic impacts. The oil industry was already providing significant mitigation projects through agency permitting of new facilities, and was reluctant to take up issues stemming back 50 to 60 years. The federal government, similarly, was leery of opening up the question of compensation for past federal leasing and production, particularly if the precedent could applied to the much broader activities in the Gulf of Mexico.

Rather than halt the process, the committee next approached the state in 1987 with a consensus proposal to be funded through the OCS Lands Act section 8(g) funds. These funds are provided as a limited form of revenue sharing from offshore oil and gas activities in federal waters.[a] Section 8(g) specifies that the funds "may be used for the mitigation of adverse economic and environmental effects related to the development" of offshore energy resources. Most states, however, have not used the 8(g) funds for this purpose.[11] California had done so earlier through a local assistance program to coastal counties and cities, which had already funded a number of projects addressing offshore oil conflicts with the fishing industry.[16]

As subsequently enacted [Chapter 1002, California Statutes of 1988], the Local Marine Fisheries Impact Program was established under the Secretary for Environmental Affairs[b] to address — but not mitigate — past and cumulative impacts on commercial fishing from offshore oil and gas activities. Given this limited scope of the impacts, the program was proposed as a 3.5–year effort with a total budget of $6.5 million. The program was scheduled to end January 1992, although legislation was introduced to extend and broaden the program activities.

To ensure the program specifically addresses the needs of all affected fishermen, an advisory committee was formed by representatives of commercial fishing organizations throughout the state. Technical advice and coordination with other programs and regulatory processes is maintained through advisors to the Fisheries Program Committee, which are drawn from the oil industry, academia, and relevant State, local, and federal agencies. Specific activities fall under seven discrete program elements. The authorizing statute provided only a general outline for these elements, and the details have been worked out to respond directly to the needs of the affected fishermen through active involvement of the Fisheries Program Committee.

Area, Gear and Technology Development

This element is applied to resource, at-sea, and economic conflicts through research of alternative fishing areas, gear, and operating technology. To address preclusion, alternative gear is developed and tested, to enable existing boats to once again fish in areas containing offshore oil and gas debris or facilities. Other research efforts target development of underutilized species or support exploration efforts to identify new fishing grounds, as a mitigation approach. Similarly, at-sea conflicts are handled through development of gear that presents a lower risk of damage from oil and gas facilities and activities. This element also has funded several market development projects that directly deal with economic conflicts. Contracts funded to date are included in the program reports listed in the Reference section.

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[a]Section 8(g) was added in the 1978 amendments to the OCS Lands Act, but with one minor exception, the required revenue sharing was not implemented until further amendment in 1985. California received $338 million in 1986 plus an additional $289 million paid out over 15 years, in settlement of its escrow account. States also receive 27 percent of all bonuses, rents, and royalties from post-1978 leases in the first three miles of federal waters, prorated on a surface acreage basis.

[b]Now Secretary for Environmental Protection

A number of the research projects in fact concentrate on testing gear types that have been developed to minimize oil/fishery conflicts in other offshore oil provinces such as the North Sea, or gear types existing elsewhere in the world but not yet introduced in California. This type of project actually serves a linking mechanism between academic research and real world use. Much of the technology to minimize gear conflicts exists in some form, but fishermen are in many cases unlikely to have the time or capital to test out unproven gear. Much of the research under this element is conducted by fishermen who are generally considered leaders in the local fleets. Technology transfer occurs quickly when other fishermen in the harbor see these researchers producing results with the new gear.

Some difficulties have arisen as this element has been implemented. One of the most important is that fishermen are not all that familiar with — nor do they like — government contracting procedures and paperwork. The Fisheries Program Committee was instrumental in trying to simplify the overall paperwork process, but the remaining requirements have in some cases limited participation in the research program. Fishermen have also been reluctant to put their concepts on the line, knowing that their ideas will thereby become public knowledge to others in the fleet. On the other hand, several individuals that began the process with this viewpoint subsequently became active proponents of getting the information out to benefit the industry as a whole. Requests for proposals have been issued annually, and interest in this element remains high. Although the proposal topics have begun to focus on problems of broader concern — as opposed to strictly being related to offshore oil and gas conflicts — this element could become an ongoing activity under any program extension.

Vessel and Gear Staging and Repair Space

This element directly addresses harbor conflicts. Through the State Coastal Conservancy, staging and repair space is being developed in harbor areas adjacent to existing production and leased areas. To some extent, this element addresses conflicts with recreational uses more than with oil and gas, given the increasing scarcity of space and facilities in California ports and harbors. In that respect, this element provides a means of mitigation or compensation for other economic conflicts with oil and gas. The specific facilities now under construction were identified through a survey of fishermen in the affected ports.[37] Each facility is intended to become self-sustaining through user fees, although the economic viability of many of the projects will require close to 100 percent usage. This element has funded essentially all of the viable projects identified in the survey; some smaller projects included in that report will be handled by local enhancement funds such as the one maintained by Santa Barbara County.

Fishing Vessel Safety, Survey and Survival Equipment

This element indirectly addresses many of the resources, at-sea, and economic conflicts by enabling fishermen to safely pursue avoidance strategies. Grants of up to $5000 per vessel are awarded for safety surveys of vessels and for purchase of safety equipment that enables fishermen to extend safely their operating range beyond areas containing oil and gas activities. To qualify, fishermen must meet specific income criteria to demonstrate they are full time fishermen, demonstrate they have been impacted by offshore oil and gas conflicts, and show that the requested equipment is necessary to extend their operations. To date, over 300 grants have been awarded, and interest in continuing this element remains high. Legislation has also been introduced to extend the safety grant element to party boat operators as well.

Sea Floor Oil and Gas Debris Cleanup Fund

This element addresses some at-sea and resource conflicts through the identification and removal of sea floor debris. As conducted by the State Lands Commission, surveys have been completed for all portions of state waters having past oil and gas activities. All the identified debris has been charted, and currently is being analyzed to establish a priority list for removal. Where the debris is identified with a specific company, the State Lands Commission is working with them to ensure removal or other appropriate remedial actions. Any remaining debris can serve as a mitigation bank which could be used in future permitting actions to provide a kind-for-kind mitigation. Instead of paying into a study fund or providing direct monetary compensation to individuals, future project applicants — oil and gas or other ocean space uses — will be able to mitigate preclusion of areas by opening up currently-precluded areas of high priority to the local fishing industry by removing debris.

This particular element has encountered several issues. Activities have focused on debris identification. Removal, particularly of large objects, is an expensive proposition for which additional program funds are now not available. Still, charting the debris provides fishermen with the information they need to avoid gear losses through snags.

At the same time, more than just oil and gas debris has been identified. Other types of debris and some hard bottom features have also been shown in the surveys, and all this data is now publicly available. These areas generally are prime fishing spots favored by individual fishermen, and they have expressed some concern that others now have access to the same information. To help avoid this problem, the survey data is presented generally in aggregated form, and hard bottom features are not included on the public charts.

Another concern is whether debris should remain or be removed. Debris causes the greatest conflicts with draggers. Hook and line gear and recreational fishermen generally target this type of seafloor feature due to its artificial reef characteristics that attract fish. Through the State Lands Commission and the Fisheries Program Committee, a priority ranking system is currently being developed that will serve as a guide as to which debris should be removed.

Finally, some of the debris areas of greatest concern lie in federal waters. This debris is associated with early production and exploration activities in federal waters conducted prior to the current post–construction survey and clean–up requirements. Other debris remains from an extensive boring program run by the State in the 1930s prior to the Submerged Lands Act. Through a cooperative arrangement with Minerals Management Service, some of the highest priority areas in the 8(g) band were included in the State Lands survey. However, the state is not in a position to devote its funds to resolving conflicts in federal waters.

For future program activities, additional monies would likely focus on debris removal. However, the expense of these operations would have to be tied closely to the potential benefits of the areas that would subsequently be opened. Additional efforts of this type are needed in federal waters, but debris survey and removal in those areas are correspondingly a federal responsibility.

Fisheries Marketing Assistance

The preceding elements largely respond directly to specific oil and gas conflicts. The marketing element is a much broader effort, and deals with the economic conflicts by recognizing that the fishing industry is affected by more than just oil and gas constraints. No specific activities have been undertaken as yet, although related market research and development has been conducted under some of the other elements.

The bulk of this work to date has concentrated on establishing a California Seafood Council. Created as an industry marketing council under the Department of Food and Agriculture, this new element was recently approved overwhelmingly through an industry referendum. The Council will be composed of both fishermen and processors, and will cover most of the fisheries harvested off California. Since the referendum, additional fisheries have expressed an interest in joining the Council.

In addition to program funds, the Council will also be supported by a levy on fish landed and handled in California. This provision provides a long term source of funding, and ensures that the marketing can become self sustaining as required by the program's statute. With the exception of the safety grant and debris elements, the Council's mandate enables it to carry on all the other elements under the Local Marine Fisheries Impact Program. Although the marketing element promises to provide the broadest long term benefits of any of the program elements, continued State funding likely will be limited given the policy implications to other industry marketing councils which are supported entirely by industry levies.

San Pedro Purse Seine Fleet Assistance

This element was included to address the specific needs of the San Pedro fishing fleets. The original concept of the program was developed primarily by fishing fleets in the Santa Barbara Channel and Santa Maria Basin area. The San Pedro fleets were not involved in the Liaison Committee process, yet by tonnage, they represent the largest segment of the commercial fishing industry. Added during the legislative process, this element can provide marketing, fuel conservation, and resource assessment assistance. As subsequently developed, this element has concentrated on resource evaluations and marketing studies of Pacific sardine. Based on anecdotal evidence, sardine populations appear to have increased substantially off California. The San Pedro wetfish fleets along with the industry elsewhere in California look to this resurgence as a promising source of future prosperity. The studies under this element, done in cooperation with the Department of Fish and Game, will serve as the basis for considering whether the current catch quota can be raised to a level sufficient to support a renewed sardine fishery in California. Although originally focused on the San Pedro fleets, this study has gained support among other members of the Fisheries Program Committee, and additional funding has been made available through the area, gear, and technology development contracts. Resource evaluations are also a possible activity of the new California Seafood Council, and the Council has been set up to enable segments of the industry — such as the wetfish fleets — to designate a portion of their levies to specific activities such as continued focussed research for sardine stock management.

Fisheries Development Corporation

The development corporation element was included in the authorizing statute in recognition that a band–aid approach to the conflicts was not in the best interests of either industry. The overall program was envisioned as a one-time assistance from the state, but a permanent vehicle was needed to continue addressing the conflicts in future years. The development corporation was intended to serve this purpose, and was to become self-sustaining through efforts of the two industries following an initial infusion of capital from the state.

As the concept has been explored, the current proposal is to utilize the California Seafood Council to serve this purpose as well. Through the industry levies, the Council will become self-supporting, and its allowable activities include those elements of the program where future activities are likely to continue to help resolve many of the existing conflicts. The Council also is capable of receiving contributions from outside sources. Through this means, the Council can become a conduit for any future oil industry mitigation or compensation funds. By doing so, future mitigation/compensation can focus on assisting the commercial fishing industry as a whole, and not focus on one-time or individual conflicts.

CONCLUSIONS

The Local Marine Fisheries Impact Program and other conflict resolution methods used in California differ considerably in what they have been able to achieve. Their "effectiveness" can be considered from several perspectives.

The type of conflict addressed varies. Mediation proved unable to handle economic conflicts, and is more amenable to space use conflicts that can be resolved with minimal cost to either party. Avoidance through means such as moratoria obviates any conflicts, but also precludes any multiple-use management. Avoidance through project design features and scheduling may resolve some conflicts with specific gear types, but still leaves residual conflicts with others. The Local Marine Fisheries Impact Program was designed to address the full range of conflicts, but also was intended to supplement and not replace the other resolution techniques. No one method of conflict resolution can handle all situations.

Most of the resolution techniques are easier to employ in frontier areas having no existing history of conflicts between the two industries. Many of the techniques such as use priorities, planning/zoning, MOAs, task forces/joint review panels, consistency, and permit conditions can only be applied to future leasing, exploration, and development. They are much harder to apply retrospectively to existing facilities and past operational conflicts. Avoidance techniques such as the creation of vessel traffic corridors can be used to modify existing activities to, in this example, prevent continued conflicts with set gear. Compensation can address past conflicts, but only if a willing party can be found to open up the question of precedent and only if the aggrieved parties are still in the commercial fishing business. The Local Marine Fisheries Impact Program is an attempt to bypass these questions. The focus is on past and cumulative conflicts; measures to minimize conflicts from future oil and gas activities must be built in through the permitting and consistency processes. The question of precedent is bypassed by statutory findings that the program is not a "mitigation" for these conflicts, but this approach is only made possible by the flow of revenue sharing from the federal leasing program. Future ocean uses not providing such revenue sharing to address onshore and other coastal state impacts will limit this type of approach of simply solving a problem rather than arguing over who is responsible for it.

Ocean use conflicts typically cross the boundary between state and federal waters. If the coastal states feel that conflicts are not being handled in federal management decisions, certain of the conflict resolution techniques enable them to develop solutions that cover both jurisdictions. MOAs, mediation, and task forces/joint review panels provide a cooperative means to work out such measures among the involved agencies. Consistency and, where onshore facilities are involved, permit conditions provide a more direct means for states and local governments to impose these measures. The Local Marine Fisheries Impact Program combines elements such as the debris removal which are largely limited to state waters, with others such as marketing and the research and development activities that apply to fishing operations regardless of their location. However, the program is funded by state monies, and its focus must remain on issues that fall under the state's responsibility.

Conflict resolution must focus on the problems, and avoid being sidetracked by handling only symptoms. Many of the conflicts from offshore oil and gas in fact intensify operating constraints on the commercial industry in California, and simply removing a project–specific conflict often does little to ensure the long-term viability of commercial fishing. Methods such as direct compensation to individuals also provide more of a temporary respite rather than solving the problem. The Local Marine Fisheries Impact Program, while focused on offshore oil and gas impacts, has attempted to deal with the industry as a whole. Specific elements such as marketing assistance have been crafted from this perspective, with the awareness that benefits to the entire industry will also accrue to the impacted fleets. Similarly, the benefits may not be possible unless they are developed in a manner that applies throughout the industry.

Finally, to be successful, conflict resolution must have active involvement from the affected user groups. The conflicts can only be "solved" if those user groups feel that the problems have been worked out. Many of the techniques depend on an agency determination of the extent of the conflict, and of what measures constitute resolution of the conflict. In the case of fishing conflicts, fishermen have to be involved in the design and operation of the resolution process, but this approach has also been hard to maintain. If given a choice, the fishing industry clearly prefers conflict avoidance. The Liaison Committee process was possible in the Santa Barbara region because conflicts were already occurring and had to be resolved. Establishing a similar process in a frontier area would be more difficult, because such an action would imply acceptance of leasing and development on the part of fishermen. Even with the committee, many local groups had reservations of becoming involved as a result of perceptions that agreeing to negotiate the conflicts meant they had to give up the option of fighting further leasing/production through the agencies. On the other hand, agencies had comparable concerns that problems were being resolved outside their permitting processes, and being presented with solutions over which they had no direct control.

In its early stages, the Local Marine Fisheries Impact Program encountered similar concerns. Fisheries groups were concerned that involvement in the elements or acceptance of the safety grants implied acceptance of offshore oil and gas. These issues were handled to some extent by the focus of the program on past and cumulative impacts. Other concerns were related to the extent of agency control of the various elements, concerns that have been heightened in some cases by the paperwork associated with the application processes. However, the program's success to date has come from the high level of involvement of fishermen through the Program Committee in the design of program procedures, setting priorities for funding, working with their constituencies in developing research proposals, and helping to select which projects, grants, and other activities merit funding through the program.

This involvement and the importance of cooperation with the fishermen is best demonstrated by the extent of industry participation. While individual associations have fought each other in the past, all have worked together on the Fisheries Program Committee and maintained its focus on assisting the industry rather than individual groups. While fishermen and handlers have seen each other primarily as competitors in price negotiations, both are now working together on California's first state-wide seafood marketing council.

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Offshore Industrial Development Fisheries Mitigation: Its Effectiveness and Recommendations for Improvement

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ABSTRACT

The impacts of oil/gas and minerals extraction on fish resources and fishing activities are offshore development issues that have received much attention. These issues have spurred discussion, research, and investments in time and money directed toward mitigating impacts.

Impacts are generally addressed by mitigating measures with little or no assessment of their effectiveness in resolving fisheries related impacts. As future proposals for industrial development are evaluated and implemented the industries and regulatory agencies would benefit from knowing what measures have helped resolve the issues.

This paper describes the effectiveness of fisheries related mitigation measures associated with oil/gas development and minerals dredging projects located offshore California and Alaska. Results from three case study analyses and a literature review are summarized.

Major conclusions indicate that physical conflicts between industries are easily identifiable. Mitigation, if adequately enforced, focusing on communication, siting projects in least sensitive areas, and reducing seafloor obstructions limits impacts. Well designed fisheries compensation and enhancement programs help to augment lost fishing opportunities, but may also trigger other impacts.

Effects on fish resources are largely unknown and therefore development of effective mitigation is less likely, unless it is tied closely to accurate, on-going monitoring. Concern about potential effects often limit the intensity or location of offshore development, and thus, affect ocean space utilization.

International Perspectives on Coastal Ocean Space Utilization
Phyllis M. Grifman and James A. Fawcett, Editors

INTRODUCTION

Assessment of offshore development mitigation is critical since coastal management policies encourage multiple uses of our oceans. The goal of most policies is to balance competing uses and needs for the benefit of local, state, and national interests. A key to the success of this balancing is effective mitigation. Without it, impacts are cumulative and worsen as the coastal environment becomes more crowded with competing recreational, commercial, and industrial uses.

"Mitigation," as defined here, is measures implemented or funded by regulatory agencies or permittees that lessen or attempt to lessen impacts of offshore development projects. The impacts and mitigation reviewed in this paper focus on offshore oil/gas and minerals mining effects on fisheries. "Fisheries" are defined, by broad definition of the Magnuson Fishery Conservation and Management Act, as fish resources, harvesting, and other activities that utilize the resource.

Impacts of offshore oil/gas and minerals mining projects on fisheries and suggested mitigation measures are described in published and unpublished literature. In addition, much information is available in regulatory agency files, in the form of environmental reviews, letters, and memos. Also, valuable information can be obtained from interviewing representatives of project developers, regulatory agencies, fishing and community organizations. Collectively, information from these sources can help assess the effectiveness of implemented measures and recommend improvements for ongoing and future projects.

Assessment begins with a literature review that summarizes impacts and mitigation measures from projects around the world. The case studies focus on the following projects: Platform Irene on the south central California Outer Continental Shelf (OCS), Endicott Causeway off Alaska's North Slope in the Beaufort Sea, and gold dredging in Norton Sound, offshore Nome, Alaska. For each study, impacts and adopted mitigation measures are identified and effectiveness of the measures are assessed. The paper concludes with recommendations for improving mitigation.

LITERATURE REVIEW

Oil/Gas

Geophysical survey operations, oil/gas exploratory rigs, platforms, pipelines, other facilities, and related operations affect fisheries. Table 1 summarizes reported impacts and mitigation measures.

Hook and line, trap, purse seine, gillnet, longline, and trawl fisheries have varying portions of fishing grounds displaced by facilities and operations on the United States (U.S.) OCS and in the North Sea. Trawlers also experience gear damage and loss from oil related seafloor debris and structures, such as subsea completions and poorly designed pipelines.[1]

Oil/gas operations in south central California preclude fishing, interfere with fishing operations, and cause competition for space in crowded harbors. Impacts on fish resources may be caused by geophysical surveys, drill muds, cuttings and produced waters discharged from facilities, and oil spills. Also, compensation payments to some fishermen purportedly divides the fishing community.[2] Similarly, Atlantic fishermen experienced conflicts with geophysical survey and oil operations supply vessels and were displaced from fishing grounds.[3]

North Sea fishing industry representatives report similar problems. They also reported that 50 square (sq) kilometers (km) of Norwegian fishing grounds were closed off due to oil operations and advocated full removal of obsolete platforms.[4] Partial removal, down to 55 m below the water surface would complicate navigation and make fishing operations more hazardous. Total removal of North Sea platforms may cost $5.8 billion (U.S.) or about $40 million per platform. Partial removal would reduce the cost by about a third, to $3.5 billion.[5] Representatives were also concerned about potential harm to fish,[4] and Scottish fishermen reported snagging trawl gear on subsea pipelines.[6]

Literature sources also offered a variety of procedures and mitigation measures to reduce impacts. Several stressed that establishing good interindustry communication can lead to cooperation and eventually compromise to resolve problems.[7,8,9] Development of oil and fishing industry umbrella groups to address identified problems was also advocated.[8,10] Such groups developed mitigation for operations on the Grand Banks of Newfoundland, including compensation to fishermen for gear loss/damage due to oil related debris, up-to-date contact lists for representatives of both industries, oil industry quarterly reports on projected offshore operations, and emergency communication plans in the event of oil spills.[10]

Newfoundland industries developed a policy that directed fishing vessels to defer to seismic vessels towing long cables to limit gear conflicts. Another approach to seismic/fishing gear interactions was tried elsewhere. California's Joint Oil/Fisheries Committee (Joint Committee) published a manual to educate the industries on their operations. The manual suggests rescheduling of seismic operations to avoid fishing activities, negotiations with fishermen to arrange for gear removal or other considerations, use of scout boats to locate fishing gear, and development of fishing gear avoidance procedures.[11] The Joint Committee also established oil support boat traffic corridors, a liaison office that serves as an information conduit and clearinghouse, and initiated studies on geophysical survey effects on fish.[2]

Scheduling operations around fishing seasons is also feasible.[12] Other measures tried on the California OCS include: locating equipment and facilities away from major fishing grounds and sensitive fish habitat areas, limiting the amount of space utilized by oil equipment and facilities, use of "underwater" or removable anchor buoys in gillnet fishing areas, pipeline laying techniques that minimize anchor scarring, use of dynamically positioned exploratory drill rigs, construction of smooth-profiled subsea pipelines, shrouding of pipeline protrusions, post-construction and exploration surveys to facilitate removal of oil related equipment and debris, use of compensation funds for gear loss/damage and loss of fishing opportunities, and replacement of displaced fishing facilities in harbors.[13] Potential impacts on fish resources may be lessened by limiting the number of seismic surveys in primary habitat and fishing areas, restricting surveys from spawning and nursery areas,[12] restricting or prohibiting offshore disposal of drill muds, cuttings, and produced waters, preventing oil spills, and using state-of-the-art oil spill clean-up equipment and techniques.[14]

Table 1

Oil/gas Impacts and Mitigation

IMPACTS	MITIGATION
1. Unanticipated. fishing activity preemption	1a. Adequate timely notification of oil/gas and fishing activities. 1b. Regularly scheduled notices/newsletters to both industries. 1c. Emergency notification procedures.
2. Uninformed fishing and oil operators, leading to gear loss/damage and fishing preemption.	2a. Locally available and informed oil industry representatives. 2b. Available and informed fishing industry representatives. 2c. Training programs and manuals for both industries. 2d. Central point of contact (clearinghouse) for both industries. 2e. Up-to-date contact lists.
3. Preemption of fishing grounds by offshore oil activities.	3a. Use of equipment and facilities that take up the minimum amount of space while ensuring adequate safety. 3b. Underwater" or removal of anchored rig marker buoys in drift fishing gear grounds (may endanger other fisheries and marine traffic). 3c. Prohibit dumping of oil related equipment and debris. 3d. Schedule oil operations around fishing seasons or daily activities. 3e. Financial compensation. 3f. Remove obsolete platforms.
4. Damage to or loss of fishing gear, and loss of fishing opportunities	3c. 4a. Pipeline laying techniques that employ proper handling of anchors. 4b. Construct smooth profiled pipelines. 4c. Shroud seafloor protrusions. 4d. Establish oil support vessel traffic corridors. 4e. Conduct post construction and exploration surveys to ensure seafloor is free of oil related obstructions.
5. Inadequate dock space in harbors. longer exists.	5a. Policies and regulatory mechanisms to ensure no net reduction in commercial fishing harbor facilities unless need no
6. Effects on fish resources and habitat	3e. 6a. Limit discharges in known habitat areas. 6b. Prevent oil spills. 6c. Use state-of-the-art oil spill clean-up equipment and techniques.

Minerals Mining

The cited literature addresses dredging for aggregates and minerals and offshore minerals mining. Effects from mineral mining may be greater then from other types of offshore dredging because processing destroys sediment cohesiveness and results in greater dispersal of tailings, according the U.S. Department of Interior (USDOI).[15] Table 2 summarizes reported impacts and mitigation measures.

The International Council for the Exploration of the Sea (ICES)[16] reported on impacts from several sand and gravel dredging operations in European waters. Loss of fishing gear from interactions with anchor lines and dredges, loss of trawl fishing efficiency from cratered seabeds, destruction of spawning grounds, seafloor substrate, and food sources, turbidity, siltation, and finally reintroduction of toxic metals into the water column were all cited as impacts.

To elaborate further, mining changes seafloor contours, which can increase either coastal erosion or deposition of sediments. The deposition can create sand spits, bars, and other navigational hazards. Turbidity reduces photosynthesis, leading to drops in production of plankton, growth, and reproduction rates of scaled fishes. Fish may abandon established migration routes or avoid congregating in traditional grounds. Turbidity may deplete oxygen levels in water and also reduce the sea's natural ability to neutralize harmful substances.[17]

Since 1977, extensive case study analysis of marine mining and tailings disposal projects has been done. At several southeast Asia tin gravel mines on the OCS, off the west coast of Malaysia, turbidity depresses biological production and coral reefs are affected by sedimentation and trace metals. Mine tailings are disposed offshore Island Copper Mine (Vancover Island, B.C.) into a fjord. Although portions of the seabed are smothered, the disturbed areas are recolonized within 12 months.[18] Crab, prawns, and salmon are harvested in the turbid waters.[19]

Disposal of copper tailings from the Bougainville mine in New Guinea into a river that drains to the sea raises levels of soluble copper in the bay, but no elevations of trace metals in marine fish are evident. However, local residents lost their river fishery.[18,19] Another onshore mine, El Salvador Copper Mine in Chile, disposes its tailings directly to the ocean. It is reported that discharges hinder harbor activities, cause modification of coastal geomorphology, turbidity and discoloration of the beach, increase trace metal bioaccumulation, kill fish, and caused the closing of a local marine resort area.[19] Effects of copper mine tailings disposed into Howe Sound off western Canada were studied 12 years after a mine was abandoned. The diversity and number of organisms in the tailings piles were significantly less than those found in undisturbed survey sites.[20]

Gold dredging operations in nearshore waters offshore Nome, Alaska have also been studied. Navigation hazards are caused by the dredge and associated anchor cables within 500 m of the dredge.[21] Turbidity was an ongoing problem as is burial of cobble areas. A survey of a site near a dredged area showed that boulders were covered with 6 in (inches) of sand 18 months after the area was dredged.[16] As for changes in seabed composition, the proportions of sand and cobble areas in dredged areas are similar to undisturbed areas within two years of dredging. Recolonization of the dredged areas is more rapid in sandy areas, compared to cobble areas, but the amount of time needed for full recovery is unknown.[21]

Eighty to ninety percent of plants and animals in the path of the dredge die from the disturbance and entrainment. Effects on a local commercial and subsistence red king crab fishery are currently unknown. Reports of catches of crab in dredged and undredged areas are conflicting, so conclusions regarding effects on crab populations and fisheries are not possible.[15]

Monitoring has detected elevated levels of nickel, lead, mercury, and copper in the water, but there is little evidence of bioaccumulation and magnification. Studies on the human population for mercury contamination showed levels in hair samples far below danger levels. Dredging also presents the potential for fuel spills from the dredge and subsequent contamination of fish nursery and spawning areas.[15]

The authors also suggested measures to reduce impacts. Environmental assessments and prohibiting dredging in the coastal zone and fish spawning and nursery areas were offered,[22] as was adoption of mining schedules compatible with local conditions.[17,23] Use of transit corridors for support vessel traffic and designation of buffer zones to avoid impacts on sensitive habitats and migration routes were also suggested.[23] Turbidity in some locations was minimized by discharging tailings at depth, both in shallow and deep water discharge sites. Preferable depths were below the photosynthesizing zone and away from areas of upwelling.[19] Alternatively, a high velocity shallow discharge reduced turbidity in Norton Sound.[21] Smothering was limited by keeping tailing piles in localized areas. Limits on levels of discharges reduced bioaccumulation and acute toxicity. Biomagnification of metals in the food chain could be avoided by conducting mining away from enclosed areas with poor circulation and a closed food chain.[18]

Study of environmental conditions prior to project development and monitoring during mining was recommended.[17] Also advocated were pre- and post-project surveys and studies, as well as short and long term monitoring during the life of a project. Environmental baseline studies and monitoring prior to a project will determine the state of existing conditions from which to judge changes caused by the project. Results from short-term monitoring for the extent and effects of turbidity, metal concentrations, and tailings settlement effects can be used to modify mining operations, if needed. Long-term monitoring would provide information on heavy metal bioaccumulation and magnification. Post-project analyses of actual impacts and an environmental audit would document the accuracy of impact predictions, cost-effectiveness of studies, and recommendations for future projects.[18]

Table 2

Minerals Mining Impacts and Mitigation

IMPACTS	MITIGATION
1. Changes in seafloor relief, leading to coastal erosion and navigation hazards.	1a. Discharge tailings into localized or previously dredged areas.
2. Disturbance of seafloor habitats and known productive fishing grounds.	2a. Designate buffer zones around sensitive areas. 2b. Compensate for lost catches.
3. Elevated levels of heavy metals in water column, leading to toxic metal bioaccumulation and magnification.	3a. Limit levels of discharge. 3b. Avoid enclosed areas with poor water circulation and closed food chains.
4. Turbidity leading to clogged fish gills, changes in feeding patterns, migration, and reduced water quality.	4a. Design discharge system to account for local water depth and circulation conditions. 4b. Designate buffer zones around known fish migration and congregating areas.
5. Destruction of fish spawning and nursery areas.	4b. 5a. Prohibit mining in known spawning and nursery areas.
6. Burial/suffocation of bottom dwelling organisms.	1a.
7. Impacts on fishing operations, including spacial conflicts and loss of fish resources	7a. Schedule mining around fishing seasons and schedules. 7b. Designate transit corridors. 2b.
8. Entrainment.	None cited.
9. Contamination of resources from fuel spills.	None cited.

CASE STUDIES

Platform Irene

Setting: Platform Irene and the related pipeline are located in the southern Santa Maria Basin on the California OCS. The 72 slot steel jacket platform is located about 5 miles offshore Point Pedernales in northern Santa Barbara County and a subsea pipeline connects the platform with onshore processing and transportation facilities.

The platform is in a productive winter halibut trawl fishery and the pipeline traverses the trawl grounds, set gill net grounds for halibut and trap areas for crab and lobster.[14,24,25] Trawl vessels fish between the three mile state tidelands boundary and the platform mooring buoys. Trappers and gillnetters fish within nearshore waters.

Oil And Gas Activity

The lease tract was acquired by Gulf Oil Company (later changed to Chevron U.S.A Inc.), Superior Oil Co. and Union Oil Co. of California (later known as Unocal) as part of federal lease sale #53. Oil was discovered on the tract on January 11, 1983. Shortly thereafter, Unocal was designated as operator, and the area was given the name of the Point Pedernales field and project. Platform Irene and the pipeline were installed in 1985 and drilling operations began in winter of 1986. The platform is expected to recover 42.8 million bbls of oil and 51.1 billion cubic ft (bcf) of gas.

Impacts

Regulatory agencies, fishing interests, and preparers of environmental documents agreed that impacts were limited to the following:[14,26,27]

- Fishing activity preemption from oil spills.
- Possible contamination of fish habitat from platform discharges, including drilling muds/cuttings and produced waters.
- Trawl ground preclusion from platform, and possibly pipeline.
- Fishing gear/vessel damage from collisions with platform, oil support boats, pipeline, and seafloor snags.
- Preemption of fishing from construction activities.
- Competition for space in harbors.
- Cumulative impacts from the project and other offshore projects in the area.

The only beneficial impact cited was the potential for mariculture activities (harvesting mussels, etc.) off the platform.

Fishermen agreed that the platform site would cause little disturbance to their fishing, as long as certain conditions prevailed.[27] Chief among their concerns was the potential for snagging, damaging, or losing trawl nets on dropped debris and other oil related seafloor obstructions. They had good reasons for concern because problems were experienced on the lease in 1983 after the exploratory drill rig left the site. Fishermen complained and Union removed a six foot corrosion cap and guide posts from the seafloor.

Mitigation Measures

Impacts were addressed by federal, state, and local regulatory agencies. State and federal mitigation measures included:[27,28]

- Use of state-of-the-art oil spill clean-up equipment.
- Restrictions on offshore disposal of oily wastes and certain drill muds components.
- Design pipeline with minimum of surface obstructions.
- Shroud pipeline protrusions to avoid trawl gear snags.
- Place mooring buoys in line with and in same water depth as platform.
- Contribution to a federal fishing gear damage/loss contingency fund.
- Company marking of equipment that could cause snags if dumped overboard.
- Use support vessel traffic routes adopted by Joint Committee.
- Conduct post-construction surveys within platform and pipeline construction zones.
- Remove artificial seafloor obstructions caused by construction activities.
- Notify fishermen of construction schedules.
- Moor construction support vessels within construction zone.
- Participation by oil support vessel operators in a federally approved fisheries and environmental training program.

Several mitigation measures imposed by the local jurisdiction, Santa Barbara County, were similar to the state/federal measures. The following lists the measures that were different:[29]

- Monitoring of pipeline construction.
- Contribution of $22,880 to a fisheries enhancement fund.
- Contribution to a local fishing gear damage/loss contingency fund.

Effectiveness Of Measures

To date, fishermen report no gear conflicts with the platform, pipeline, anchor scars or debris.[24,30,31,32] Table 3 elaborates on the effectiveness of specific mitigation measures.

Table 3

Platform Irene Mitigation

MITIGATION	EFFECTIVENESS STATE/FEDERAL MEASURES
1. State-of-the-art oil spill equipment.	1a. No reported oil spills to test equipment.
2. Restrictions on drilling muds/ cuttings and produced waters discharges.	2a. No reported violations of discharge limitations.[33] No assessment of impacts available, so effectiveness is unknown.
3. Pipeline designed with minimum of obstructions and protrusion shrouds.	3a. No reported snags from pipeline.[24,30,31,32]
4. Placement of buoys in same water depth and in line with platform.	4a. Trawlers can fish within 1/4 mile of platform.
5. Contribution to federal contingency fund.	5a. Claims often take as much as six months to pay, due to lack of funds.[30] Other funds are needed for timely payments. See 15b.
6. Company marking of equipment.	6a. Equipment that caused problems after exploration was picked up by Unocal. No recent snags have been reported.
7. Use of support traffic lanes.	7a. Reported problems with oil support vessels not using lanes. Santa Barbara county investigating problems, since condition was also required by county.
8. Post-construction surveys.	See 13a.
9. Removal of artificial obstructions.	9a. Surveys did not reveal obstructions. Removal not necessary.
10. Notification to fishermen of construction schedules.	10a. Fishermen received notices in a local monthly newsletter and through Joint Committee. Fishing vessels were hired to act as scout boats during pipeline construction.[30,31] Construction occurred during times of limited fishing.[24,31,32,34] No reports of conflicts.
11. Moor construction support vessels within construction zone.	a. No reported problems.[24,31,33]
12. Fisheries and . environmental training program	12a. Training was conducted at least through early 1990.[35] Problems with sporadic use of vessel traffic corridors indicate that augmenting program with information on lanes may help inform support vessel operators of importance of lanes.

MITIGATION	LOCAL MEASURES
13. Monitoring of pipeline construction.	13a. No reported snags from fishermen.[24,30,31,32,34] The required surveys and monitoring showed evidence of scarring, but the scars could not be attributed to construction activities.[35]
14. Contribution of $22,880 to fisheries enhancement fund.	14a. Effectiveness is questionable, see discussion below.
15. Contribution to fisheries contingency fund.	15a. Loans have been made to fishermen for gear damage that could not be attributable to a specific project. Is an effective "bridging" program while waiting for payments from federal fund.

The local contingency fund was established because effectiveness of the federal contingency fund is dubious. It is administered by National Marine Fisheries Service, but funds disbursement is requested by the federal administration and authorized by Congress. Often, the requests are less than needed to pay the claims.[30] Claims take as long as 6 months to process, so the local fund provides bridge loans to eligible fishermen waiting for payment from the federal fund. County funds are used to address gear damage in waters directly offshore Santa Barbara County only.

The enhancement fund was used to pay for capital and operating expenditures to enhance the fishing industry's ability to catch, land, and process commercially valuable fish. To date, most of the funds have been used to install an ice machine in Santa Barbara harbor, located in the Santa Barbara Channel. The fisheries enhancement fund raises the issue of local government trying to address regional and cumulative impacts. The preemption impacts affect mainly fishermen whose home ports are Morro Bay and Port San Luis, within San Luis Obispo county. The Santa Maria Basin, in general, is mainly fished by fishermen from these ports, because weather precludes most Santa Barbara boats from venturing north of Point Conception. Likewise, most San Luis Obispo fishermen rarely travel to Santa Barbara to fish. Facilities developed in Santa Barbara harbor will offer little compensation for impacts from the Unocal project.

Another program in California (Local Marine Fisheries Impact Program) helps to offset impacts to the fishing fleet. Support comes from OCS revenue sharing funds. The program funds study of alternative fishing gear and methods for use in impacted areas, safety gear grants, seafloor debris survey and clean-up, vessel and gear staging and repair development, and seafood market development and marketing, to help offset offshore oil impacts attributed to development occurring prior to installation of Platform Irene. Although the program does not address impacts from the platform, it can serve as a model for addressing industry-wide programs.

Endicott Causeway

Setting: Endicott oil and gas field is located about 10 miles northeast of Prudhoe Bay, Alaska. Maximum water depths in this part of the Beaufort Sea are

14 ft. The extremely cold weather causes the Arctic ice sheet to extend to the North Slope shoreline during winter. The ice freezes to 6 ft in depth and persists for about nine months of the year.[36]

The fish of most concern are anadromous and predominant species are: Arctic cisco, least cisco, broad whitefish, and Arctic char. These fish need the eight to twelve weeks of ice-free water conditions to get nearly all (at least 90%) of their yearly supply of food.[37] The fish prefer warmer, estuarine and less saline nearshore waters to the colder, more saline offshore waters. These fish are an important subsistence food for villagers living on the Beaufort Sea. The only commercial fishing operation occurs on the Colville River, west of Prudhoe Bay, and targets on the anadromous species.

Oil Operations

The Endicott development has eight owners. British Petroleum Exploration (BP) has a 56.78% interest in the field, and as such, is the operator. Other equity owners include Exxon, Union, Amoco, ARCO, Cook Inlet Region, Inc., NANA Regional Co., Doyon, Ltd.[37] The last three are Alaska Native corporations. The state of Alaska holds a 12.5 percent royalty interest in all oil produced on the North Slope, including Endicott.

Endicott is the only offshore producing field in the Beaufort Sea. Drilling and production occurs from two artificial islands located approximately 2.5 miles offshore the Sagavanirktok River delta. A 3 mile gravel causeway or levee that roughly parallels the shore links the two islands. A second causeway, about 2 miles in length, connects the offshore complex to the river delta. The connecting portion was constructed with two breaches or bridge portions that facilitate flow of the estuarine waters. The causeways support a two lane vehicle access road and elevated oil pipeline. The road and pipeline continue across the delta to the mainland and eventually to the Trans-Alaska Pipeline.

Production facilities were constructed ahead of schedule and for slightly over $1 billion, about half of the estimated cost.[38] Oil production began in October 1987 and current production is at 100,000 barrels (bbls)/day. In 1992 production is expected to start its decline until the end of the productive life of the field, projected in 2008.

Impacts

Development of the Endicott oil field was originally proposed in 1982 by Sohio Alaska Petroleum Company (Sohio), later changed to BP. The proposal was similar to the above description, but had no breaches. Impacts identified in the Environmental Impact Statement (EIS) and regulatory permits included:[38,39]

- Changes in Beaufort Sea water circulation.
- Loss or significant changes to the river delta.

- Harmful effects on anadromous fish due to water circulation changes.
- Degradation of water quality from drilling muds/cuttings, produced waters, and other ocean discharges.
- Potential harm to marine environment from oil spills.

The proposed project was estimated to impact over 40,000 acres of the river delta. The projected impact on water circulation, fish, and delta were so significant that the EIS recommended an environmentally preferred alternative that called for two unconnected gravel islands and subsea buried pipelines to connect the facilities to shore. This alternative would reduce the amount of affected area to 12,300 acres.[39]

Monitoring Requirements and Mitigation

The EIS suggested the project could be mitigated by constructing the causeway with breaches. If the project had 1,000 ft of breach, impacts to the delta were projected to be nearly 40,000 acres (62.5 sq. miles). The mitigation required by the regulatory agencies included:[40]

- A total of 700 ft of breach, split between a 500 ft and 200 ft portion.
- Restrictions on flow rates, oil discharges, content of drill muds, and temperature increases in receiving waters.
- Oil spill contingency planning and drills.

Extensive monitoring was also required and included:

- Data collection on water temperature, and salinity differences, if any, in the vicinity of the causeway and drilling islands.
- Data on water circulation to detect changes, if any, caused by the causeway.
- Levels of certain contaminants in the water column, sediments, and selected species.

The water temperature and salinity (fish habitat) monitoring was originally overseen by a technical committee comprised of representatives from the permittee, regulatory agencies and local government. Later monitoring was overseen by local government and another technical committee. The U.S. Environmental Protection Agency (USEPA) oversaw the monitoring of the discharges.

Results

The effectiveness of the breaches is a major issue that remains to be resolved. As explained below, the results of fish habitat monitoring were inconclusive and led to different conclusions by the agencies, BP, and local government. The cost of the monitoring purportedly has cost BP over $30 million.[40] Discharge monitoring led to an innovative drilling muds/cuttings disposal method that has significantly reduced the levels of discharges from Endicott.

- 700 ft of breach. The regulatory agencies contended that the causeway significantly altered water circulation by causing cold ocean water upwelling in the path of migrating fish. They concluded that fish would have a limited ability to obtain sufficient energy for survival, growth, and reproduction.[36] Therefore, they advocated replacement of 1,300 additional ft of causeway with a bridge. BP claimed the agency conclusions were not supported by the data. The impacts on fish of limited changes in circulation and salinity and temperature levels were reported to be insignificant and much less than reported by the agencies.[41] The local government held a third view. It also believed the agency assessment was inconsistent with the data. However, it claimed that additional monitoring should occur before conclusions were made regarding the significance of impacts, and thus regulatory requirements for additional mitigation.[42]

Eventually, the permitting agency (U.S. Army Corps of Engineers (COE)) decided the additional 1,300 ft of breach was necessary to reduce the impacts. However, BP has not yet been required to construct a new bridge. Currently, a draft agreement between BP and COE that calls for construction of a new breach and an end to the required fish monitoring, is under review by the agencies and public.

- Discharge limitations. Meeting USEPA discharge criteria was difficult, because of the shallow water depths and severe weather.[43] Beginning in 1987, BP began reinjecting muds and waters in wells at the drilling islands. Later BP began reclaiming the cuttings. Cuttings are either washed and made available for use on local roads or ground up for injection into wells. The effluent is injected about one mile below the earth's surface, into the cretaceous zone, which is sealed by impermeable layers of rock.[44] One hundred percent of the muds and cuttings from Endicott are recycled or re-injected.[45]
- Oil spill contingency. BP is updating its oil spill contingency plan to meet new state requirements. No major oil spills have been reported from Endicott.

Norton Sound Gold Dredging

Setting: Recent offshore gold dredging activities occurred along the southern coast of the Seward Peninsula offshore Nome, Alaska. Norton Sound is a shallow body of water, with depths ranging from 60 to 75 feet (ft) as far as three miles offshore. Predominant fish species include red king crab, several species of demersal fish, salmon, herring and other pelagic fish. In the immediate vicinity of dredging activities, king crab is the predominant subsistence and commercial fishery. Nearshore fishing occurs during winter when holes for pots are drilled through the sea ice. Nearby, salmon and herring are harvested commercially and these and other fish provide food for marine mammals and subsistence harvests. Salmon spawn in local rivers close to dredging operations.

Offshore Mining Activities

Gold dredging was conducted in state waters by Western Gold Exploration and Mining Company (WestGold). WestGold began mining in 1985 and operations ceased in the fall of 1990. Dredging was seasonal each year, beginning after ice break-up in late spring and continued until the ice returned in the fall. Since the start of operations and through the 1989 mining season 105,960 ounces of gold were recovered.[46]

Mining operations were conducted with a large bucket-line dredge called the BIMA. It is 560 ft long, 140 ft wide, 145 ft or 14 stories high and is the world's largest active offshore mining vessel. On a yearly basis, about 50 to 200 acres are mined.[46] About 95% of the dredged material is dumped back into the water and contains seawater and tailings.

Impacts

Potential impacts were identified during the permitting process and included:[46,47]

- Effects on subsistence uses by limiting accessibility to traditional areas, driving animals away, and causing loss of habitat.
- Effects on commercial crab fisheries.
- Impacts on offshore fisheries and habitat areas.
- Bioaccumulation of mercury and other metals in the human food chain.
- Disruption and smothering of the seafloor habitat.
- Degradation of the marine environment by excessive levels of turbidity.
- Blocking of salmon migration by turbidity plumes.
- Destruction of crab habitat.
- Contamination of nearby fish spawning and nursery areas due to fuel spills.

Monitoring Requirements and Mitigation Measures

Monitoring was required on the following:

- Pre- and post-mining distribution and abundance surveys of bottom species, including king crab and their prey.
- King crab feeding habits.
- Heavy metal bioaccumulation in king crab and other selected organisms.
- Seabed recolonization rates.
- Pre and post mining seafloor and substrate composition.
- Turbidity levels.
- Dissolved oxygen levels.
- Concentration of metals in the water column.
- Concentration of metals in sediments.

Required mitigation measures included:

a. Regulatory agency approval of a water intake system.

b. No dredging within 100 ft of mean lower low water (MLLW), or within a one mile radius of the mouths of anadromous fish streams.

c. If mining or the turbidity plumes occurred within 300 ft of MLLW, WestGold would coordinate with regulatory agencies to avoid conflict with fish migration and subsistence fishing.

d. Course tailings would be discharged through the bottom of the barge into the dredged trench.

e. Fine tailings would be discharged directly into the trench through a 24 inch pipe.

f. No mercury was to be stored on the dredge.

g. Processing of the separated material was to be done at an offsite facility.

h. Dredge spoil piles that occur on the sea bottom outside the dredged trenches were to be marked with buoys or leveled to avoid navigational hazards.

i. Discharge of floating solids, visible foam, or oil in amounts to produce a surface sheen was prohibited.

The monitoring program was flexible in that it was changed based on the results of previous years work. In addition to monitoring, a literature review summarizing available information on the biotic community and physical-chemical properties of the study area was required.

A project review committee met quarterly to oversee the mitigation and monitoring programs. Specifically it: 1) coordinated compliance with permit conditions; 2) reviewed results of annual monitoring studies; and 3) facilitated resolution of issues and transfer of information. Committee membership included WestGold and its consultants, the University of Alaska, state and federal regulatory and wildlife agencies, and local/regional governments and special interest groups, including the Bering Sea Fishermen's Association. A general consensus of the participants was that the Committee was an excellent forum for addressing the socio-political concerns, understanding the issues, and encouraging communication between the parties.[48,49,50]

Results

After four years of study several issues were resolved, while others were still pending.

Monitoring Results:

• The crab and prey species studies found that crab utilize both disturbed and undisturbed areas and their feeding patterns did not change.[15]

• Observations regarding crab catch levels presented conflicting information. Fishermen reported a dredged area was barren,[50] but subsistence harvesters have not detected a change.[51] Monitored catches from dredged areas were similar to catches in undredged areas.[15] Also, annual comparisons were inconclusive. In 1988 catches varied; however, in 1989 catches in dredged areas were significantly smaller than catches in undredged sites.[15]

• Water column samples found concentrations of copper, lead, and nickel were elevated above health standard level criterion. Mercury, arsenic, chromium, zinc, and cadmium levels were below the criterion.[15]

• Copper, lead, and nickel were generally released in particulate form, lessening effects of bioaccumulation. Although lethal and sublethal effects were considered likely, evidence was lacking regarding bioaccumulation and magnification in marine species.[15]

• Metal concentrations in disturbed sediments were found to be within normal ranges.[15]

• Seafloor monitoring for changes in substrate types and recolonization rates in disturbed areas found smoothing of the dredged areas to preexisting, relatively flat conditions occurred more rapidly in shallow nearshore areas subject to ice erosion and higher energy waves.[46] Bathymetric surveys showed dredging in course grained material affects areas 1.5 to 1.8 times larger than the dredged areas.[15] USEPA speculated that sandy areas may take a minimum of five years to recover, but cobble areas may take a minimum of ten years.[52] USDOI reported that insufficient data exists to predict rates of recovery and that dredged areas may be permanently changed.[15]

• Turbidity was greater than originally anticipated, due to a high sediment silt content and difficulty in designing an appropriate discharge system.[15] After four years of experimenting with different configurations the optimum design appeared to be a pipe 20 inches in diameter with a flexible hose that extended nearly 9 ft into the water and a high velocity discharge.[53] In 1989 turbidity levels averaged 52 nephelometric-turbidity units (NTU's), about 40 NTU's above natural conditions.[15] Table 4 compares required mitigation with reported effectiveness.

Table 4

WestGold Offshore Mining Mitigation

MITIGATION	EFFECTIVENESS
1. Screened water intake system with velocity limited to .5 ft./second	1a. Fish mortality was limited to acceptable levels.[54]
2. Buffers established close to shore and in proximity to mouths of an adromous fish streams.	2a. No observed effects on salmon migration and related fisheries.[54]
3. Course tailings disposed in dredged trenches.	3a. No observed coastal erosion/ sedimentation attributed to the project.[54] 3b. Effects on crab catches unknown, results of crab catch data inconclusive.[15]
4. 24 in discharge pipe for disposing fine tailings.	4a. Not effective. System redesigned, but turbidity levels still averaged 40 NTU's above background.[53,15]
5. No chemical processing allowed on dredge.	5a. Little if any mercury contamination.[15]
6. Leveling or marking tailings piles.	6a. Keeping tailings to within six ft of water surface limited navigational hazards.[21,50,54]
7. Limits on sewage and oil discharges.	7a. No reported spills

CONCLUSION

Recommendations

Recommendations are based mainly on the results of the case study assessments. Many are supported by information contained in the literature review.

Oil/Gas development

Recommendations, based on the Platform Irene study:

- Consider study of effects of drill muds and cuttings on sandy or muddy seafloors. Monitoring is occurring on rocky bottom sites. Proposed soft bottom monitoring has not begun because the preferred site has yet to be developed.[55]
- Confer with fishing interests when designating sites for mooring buoys and construction related facilities. Attempt to limit space preclusion, based on discussions and safety requirements.
- Properly fund federal contingency fund. State and local governments may want to establish local contingency funds to augment the federal fund.
- Require use of oil support vessel lanes.
- Adequately notify fishing interests of construction schedules. Time notifications should be compatible with local needs; issue notices on a regular basis.
- Hire scout boats to monitor fishing activity around construction sites. Use of fishing captains utilizes their knowledge and expertise of the fleet and ocean conditions.
- Schedule construction around fishing seasons and activities.
- Require pre- and post-construction surveys for evidence of seafloor obstructions. Surveys prior to construction would identify existing seafloor conditions, so problems caused by construction could be more readily identified.
- Develop publicly funded fishery enhancement programs to address the extent of unmitigable impacts. Local programs may not fully address regional problems, so statewide or regional programs may be more appropriate.

Recommendations, based on the Endicott study are:

- Establish monitoring programs that will answer identified issues and questions.
- Question the use of offshore causeways.
- Carefully consider environmentally preferred alternatives when permitting projects. Base analysis on accurate economic and technical feasibility review.
- Require thorough on-going monitoring when requiring mitigation that has not been tested nor shown to reduce impacts to insignificant levels.
- Assess feasibility of reinjecting and recycling muds, cuttings, and produced waters, to limit ocean discharges. This method of disposal is feasible for the North Slope; however, a study was done for the California OCS in 1985 that concluded that reinjection was not feasible.[56] This study was completed prior to BP's research and development, so reconsideration of the method for the California OCS may be prudent, in light of BP's success.

Gold dredging

Impacts from WestGold operations were caused by limited operations, and generally the mitigation was appropriate for the level of operations. The project was treated as a prototype experiment and regulatory review did not consider cumulative impacts. These impacts are currently unknown, as are several of the impacts from WestGold dredging. Recommendations are:

- Design water intake systems to limit effects from entrainment.
- Establish buffers around sensitive areas, including mouths of anadromous fish streams, fish nursery, spawning, and congregation areas.
- Design tailings discharge systems compatible with local conditions. Monitoring of turbidity will help redesign existing systems, if necessary.
- Monitor tailings piles and develop discharge criteria to prevent navigational hazards.
- Schedule mining operations around fishing activities.
- Carefully consider cumulative impacts in areas already subject to offshore development. Design appropriate project and mitigation.

CONCLUSION

The more successful mitigation measures were coupled with adequate monitoring to assess the effects on impacts. Conversely, monitoring does little good for limiting impacts on the environment if results are not used to develop adequate mitigation. For example, when monitoring showed that mitigation was unsuccessful, i.e. WestGold and BP operations, systems were redesigned to improve mitigation effectiveness. Monitoring also acts as enforcement measures to ensure mitigation is implemented.

The assessment also demonstrates that impacts on fishing activities are easily identifiable, and mitigation can be developed to limit impacts. However, impacts on fish resources are largely unknown and vary from region to region. Therefore, development of effective mitigation is more difficult. In some cases, avoiding sensitive locations may be the only acceptable alternative.

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23

Development of Coastal Wastelands Through Ocean Coupled Solar Ponds — Power, Fresh Water, Marine Chemicals, and Aquaculture Farms for the Growth of Rural Economies in Developing Countries

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ABSTRACT

Ocean coupled solar pond power plants utilize warm water (85°C) through salt gradient, conventional solar pond technology and cold water (15°C) drawn from the edge of continental shelf (200-220 m) for power generation. Thus the temperature difference utilized is around 70°C. These power stations can be located in tropical coastal regions and have several distinct advantages over conventional OTEC/solar pond power plants. Cold water is rich in nutrients and is free from pathogens and hence ideal for aquaculture. The waste heat could be utilized for vacuum flash distillation for fresh water. The cold water can further be utilized for the production of salt and marine chemicals. In an open cycle flash method of power generation, water is automatically produced as the by-product.

The paper discusses the technologies involved in the global scenario. These ocean coupled solar power plants could be set up in isolated areas for long durations where the width of the continental shelf is comparatively small. Several places along the tropical coastal belt, especially the African coasts, are ideal. Apart from the by-products, these projects are labour intensive, generating employment to skilled and unskilled workers and are ideal for coastal communities in developing and underdeveloped countries where most of the coastal wastelands exist. The authors examine various existing technologies and the potential socio-economic benefits of such projects.

International Perspectives on Coastal Ocean Space Utilization
Phyllis M. Grifman and James A. Fawcett, Editors

INTRODUCTION

Coastal ocean space may be considered as extending from the high water line to the wind induced sand carpeted region with little or no fresh underground water within which salt intrusion takes place. The area is without any vegetation and is considered coastal wasteland for all practical purposes. On the seaward side, coastal ocean space may extend to the edge of the continental shelf, and landward, comprises the sand dunes and the intertidal regions. It is in this area where several major rivers enter the sea and deltas are formed. It is in this area the harbors are located, and major human activities are confined to this coastal ocean space. Interspersed among the various cities and the habitats are conglomerations of communities mostly living on the fisheries. Slightly remote from these areas one can find vegetation and irrigated crops, provided there are fresh water resources.

The various countries bordering oceans can be classified into three types. When the individual (family) income of the majority of families far exceeds the expenditure for daily necessities like housing, food, clothing, children's education, etc., the society may be termed affluent and the country is categorized as advanced. The per capita energy consumption is very high and their resources are extremely good. We categorize the developed countries as those countries in which the majority of the families would have just enough income to meet their needs. In the underdeveloped countries, the majority live well below the standard levels. In other words, their income is far below their necessities.

Coastal ocean space comprises beaches of different categories interspersed by rivers and rivulets, which offer a variety of types of recreation. It is primarily the first category of the people who visit these places for boating, surfing and other water sports and entertainments. In the second category, even though the countries are well developed with fairly good industrial support and infrastructure, the majority will not be able to utilize coastal ocean space for recreation. In the third category, people have neither the means nor the capabilities to utilize coastal ocean space for entertainment. Thus, coastal ocean spaces are nearly unused. In this paper, we present a program for the socio-economic benefit of the semi-skilled and unskilled population who stay along the vast coastal wastelands. The project envisages the construction of an ocean coupled salt gradient solar pond power station. In this system, we pump cold sea water from a 200 m depth for condenser cooling and this water can be used as a resource for salt production and aquaculture.

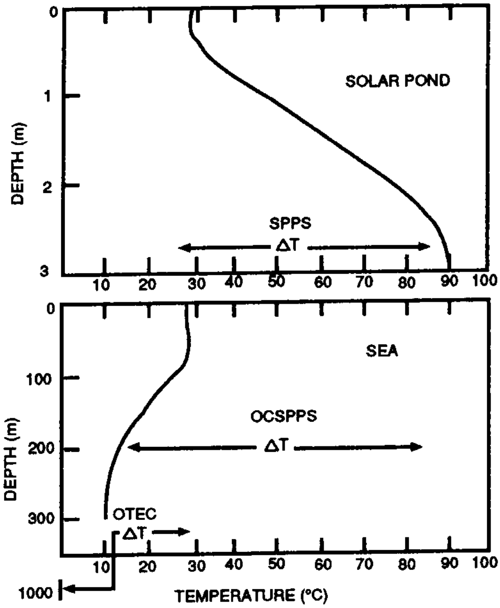

Figure 1. Distribution of temperature in a solar pond and tropical ocean. Available ΔT for solar pond, ocean coupled solar pond and OTEC power plants are also shown.

OCEAN COUPLED SOLAR POND POWER STATION (OCSPPS)

The ocean coupled solar pond power station is a concept presented in earlier writings.[1] In fact, it is a hybrid between a solar pond power station (SPPS) and ocean thermal energy conversion plant (OTEC).

The solar pond is an artificially constructed tank, 2 to 3 m deep, with a black bottom of suitable material. The tank is filled in such a manner that there exist two convecting zones at the top and the bottom, separated by a nonconvecting zone. The incident solar radiation is absorbed at the bottom of the tank and the bottom water is heated. Because of the density (salinity) structure in the pond, the warm water is confined to the bottom convecting zone, even though temperatures may be as high as 90°C. An excellent review on non-convecting solar ponds is given by Tabor and Weinberger.[2] In SPPS, the warm water is used as a heat source and the surface sea water at a temperature of 25-30° as a heat sink. On the other hand, the ocean thermal energy conversion plants utilize the surface seawater as the heat source and cold water from a depth of about 1000-1200 m as the heat sink. The temperature difference (ΔT) utilized for power generation is about 20°, in contrast to about 55° in the solar pond power station. The ocean coupled solar pond power station proposes to produce hot water at about 85° through the construction of the solar pond built on coastal wastelands and to use the cold water at about 15° drawn from a depth of 200 m as a heat sink. Thus the temperature difference is about 70°. Figure 1 shows the thermal structure and associated ΔT in the solar pond, the ocean coupled solar pond power station and OTEC.

OCSPPS has a number of advantages over the OTEC and solar pond power plants. IN OCSPPS the Carnot efficiency, which depends upon the temperature difference ΔT, is about 16 whereas it is 3.4 and 12 respectively for the OTEC and SPPS. The corresponding Rankine cycle efficiency is higher in OCSPPS. In the OCSPPS, seawater is pumped from a depth of 200 m whereas the OTEC plant requires water from a depth of 1000 m or more. Because of poor efficiency, large volumes of water are needed for energy transfer. Attendant problems like the release of CO_2 in OTEC plants are constraints. These plants will be probably located on offshore platforms and transfer of energy to the user is a major problem. In contrast, the cold water drawn from a depth of 200 m for OCSPPS will have nearly the same concentration of CO_2 as the surface water. This water, rich in nutrients, can be used as a resource for the development of aquaculture. Some of these aspects are presented in the later sections. In the following, we shall discuss areas best suited for OCSPPS in the global context and the technologies which may become a part of the total facility. The energy budget for a 1MW plant is presented for a community of 2000 families with rural background. In Appendix I, we provide a detailed computation.

AREAS SUITABLE FOR OCSPPS

The prime considerations for locating the OCSPPS are:

1) High insolation.
2) Cloud free regions.
3) A narrow continential shelf.
4) Availability of coastal ocean spaces and wastelands in low lying areas.
5) Local climate conditions.

The incident solar energy is a function of the latitude. There is a sharp drop of incident solar radiation beyond the tropics and intuitively the ideal locations for the development of solar plant power stations are the tropics. Figure 2(a) shows the annual mean incident solar radiation at the surface of the oceans over the region between 40°S and 40°N; the annual mean radiation varies between 200 and 120 kcal/cm². In the tropical oceans, the annual mean radiation exceeds 180kcal/cm².[3] Figures 2(b) and 2(c) show the distribution of temperature at surface and at 200 m[3] in the most tropical oceans respectively. One can see clearly that over most of the regions, the temperature at 200 m varies considerably, centered around 15°, and this may vary marginally from season to season. Thus, the tropical regions are also ideal from the point of view of the availability of cold water. Figure 3 shows the bathymetry (1000 m isobath) adjoining the landmass bordering the Indian Ocean.

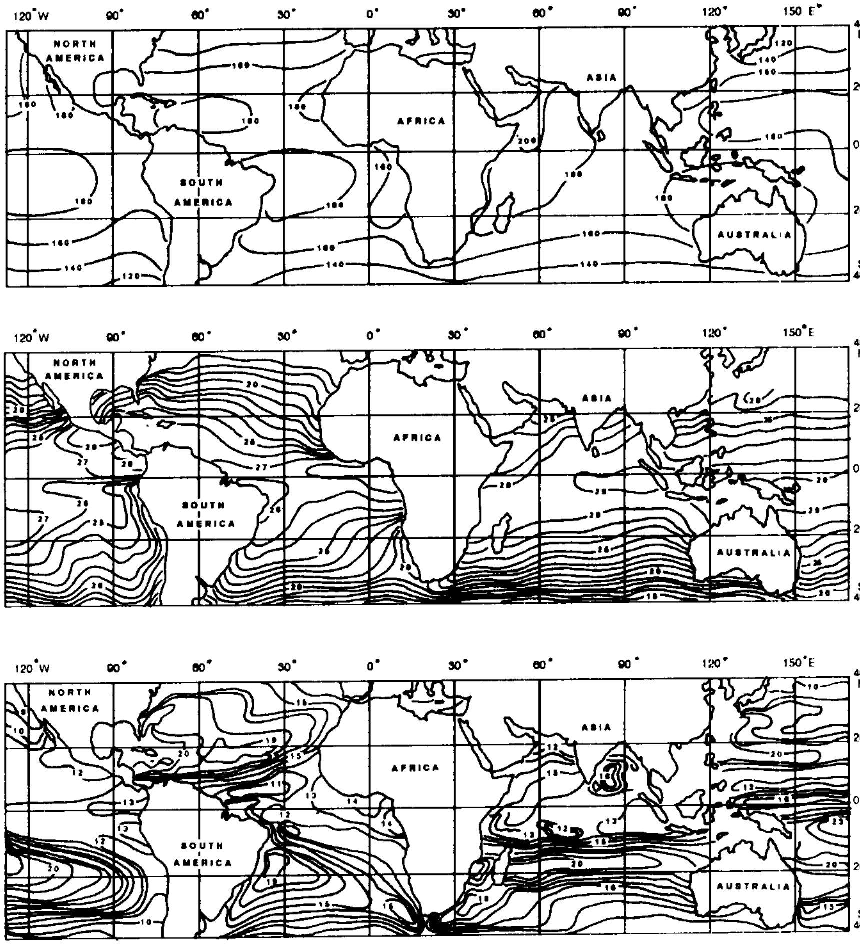

Figure 2(a). Annual mean distribution of global solar radiation at the ocean surface
(b). Distribution of temperature at the sea surface of the world oceans
(c). Distribution of temperature at a depth of 200 m in the world oceans

The continental shelf is very narrow along the African coast, Saudi Arabia, Pakistan and to some extent along certain portions of India and western Australia. Madagascar and the other islands have cold sea water available within a few kilometer from the shore. A close examination of the bathymetric charts in the tropical region suggests that the ocean coupled solar pond power stations could be located along the east coast of Africa, Arabia and in some regions of southern India adjoining the east coast and at several other locations provided there are enough coastal wastelands.

Most of the countries which lie in the tropics are underdeveloped with meager freshwater resources. The data presented earlier on insolation, temperature variations at surface and 200 m and the width of the continental shelf indicate the regions which would have maximum socio-economic impact by OCSPPS (Figure 4), though additional data are needed.[4] In the Indian context, over Tamil Nadu and Andhra Pradesh bordering the east coast of India, the incident solar radiation level is fairly high, 5-6 kW-h/m^2. The width of the continental shelf varies between 10-25 km. Several thousand hectares of wasteland is available between the major cities and the populations living in these belts may be categorized as underdeveloped, needing socio-economic development.

A comprehensive analysis of the climatic features of the area is also essential. Cyclones could be a major threat for the solar pond. The soil and subsoil characteristics, groundwater table and its variations determine the design features of the solar pond. Seasonal weather characteristics need to be investigated for optimization of extraction of power and for maintenance works.

Since the quantum of power generation depends upon the daily input of solar radiation, monitoring atmospheric conditions is essential. Evaporation processes also play an important role on the salinity structure of the pond and replenishment of water must be on a routine basis. Proper precautions need to be taken for maintenance of the pond.

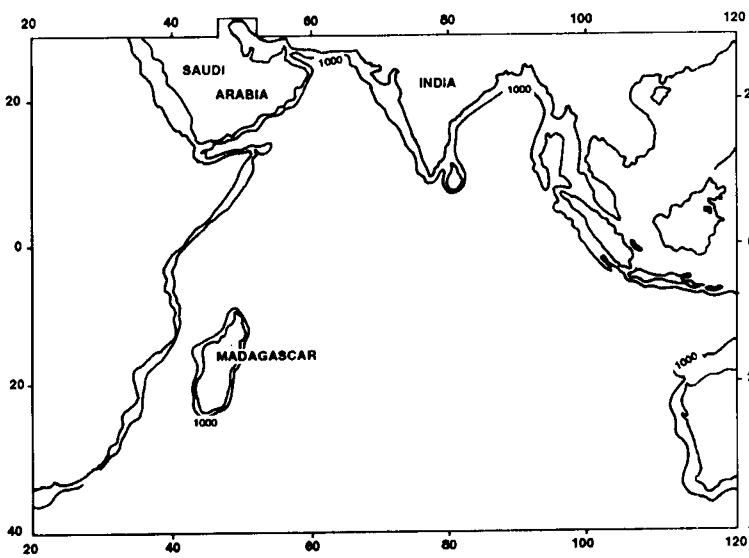

Figure 3. The width of the continental margin in the Indian Ocean

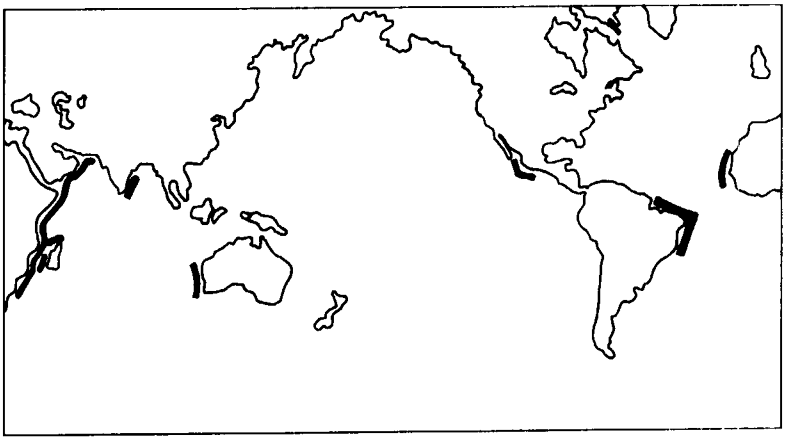

Figure 4. The coastal area of the world where conditions are favorable for establishing OCSPPS.

POWER PLANT

The solar pond supplies the hot brine at about 85°, as the source of heat and the cold seawater of about 15° obtained from about 200 m depth serves as the heat sink. The working of thermal energy conversion is shown in Figure 5. The power pack consists of an evaporator, condenser, turbine, generator and the Freon pump. These components are to be designed on a detailed analysis. Initially, Freon-11 has been chosen as a working fluid for its high efficiency in a closed loop cycle. Its thermodynamic properties are suitable to work between temperatures 15-85°.[5] The suitability of other working medium are also under investigation.

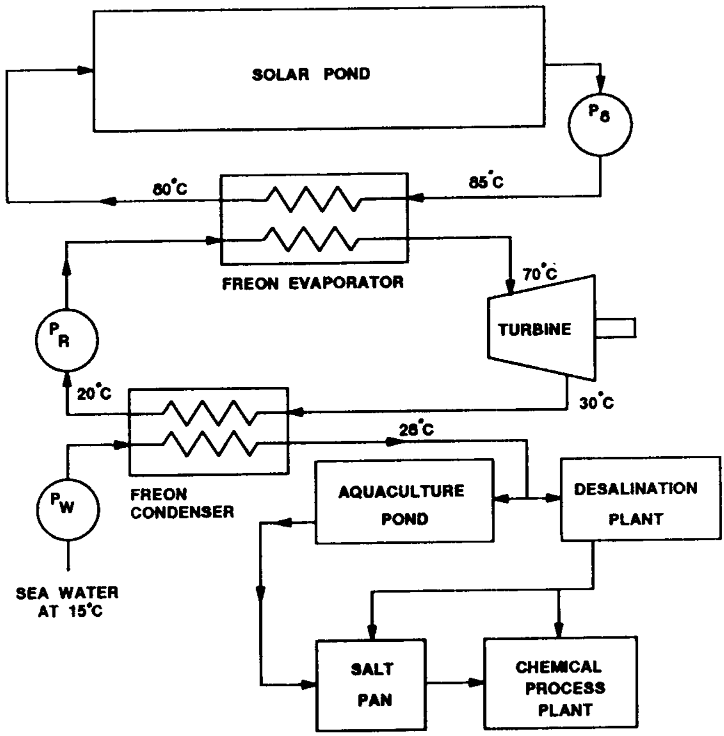

Figure 5. Schematics for presentation of the working of the power plant of the OCSPPS

Freon-11 extracts heat from the hot brine pumped from the solar pond through the evaporator. The superheated Freon vapors enter the turbine at about 70° and expand isentropically driving the turbine, generating power. The vapors leaving the turbine at about 30° are further condensed in the Freon condenser to about 20° by the incoming sea water at 15° pumped from about 200 m depth. The cooling water temperature will be raised to around 28°, absorbing latent heat of condensation of Freon vapors. The Freon condensate is pumped back to the evaporator and the cycle is repeated for generation of power. For 1 mW power plant the liquid Freon-11 pumping requirement is estimated to be approximately 0.05 m^3/sec (see Appendix I).

PIPELINE LAYOUT

For pumping cold water from a depth of 200 m we propose laying a pipe extending from the edge of the continental shelf to the shore where it is buried underground so that waves breaking near the coast have no effect on the pipe. A pipeline with a very low thermal conductivity is chosen. As the water is drawn from 200 m, we do not envisage serious bio-fouling within the tube. The energy required to pump sea water is a function of the diameter of the pipe, the friction factor, the length of the pipeline and the require volume flux. We envisage two alternative techniques for pumping as shown in Figure 6. Figure 6(a) shows direct pumping whereas Figure 6(b) shows an inverted manometric technique for siphoning from a depth of 200 m. The cooling water requirement for 1 mW power plant is estimated at 220 1/sec for the Freon closed cycle plant (Appendix I). The pumping power requirement and plant efficiency for pipes of different diameter and length are shown in Figure 7(a) and Figure 7(b). The plant efficiency and pump power varies as a function of pipe length and diameter of the pipe. For example, a pipe with diameter of 0.6 m and 15 km long will need a pump power of 0.050 mW.[6] As such the power requirements for hot brine pump and Freon pump and for the cooling water pump are low compared to the heat supplied by hot brine. The Rankine cycle efficiency is around 9.45%. As the pipeline length increases or the diameter of pipe decreases, additional power is needed to pump the equal volume of cold water.

The power plant cost will be minimum for the regions where cooler seawater is available close to the shore. In case of wider shelves a higher suction head is encountered with narrow pipes and there will be a need to install submersible pumps. The task of installing submersible pumps at sea, laying the associated power cables and the maintenance are all cumbersome. The pump and the power cables are exposed to the vulnerable sea climate. This can be avoided by inverted manometer technique as shown in Figure 6(b).

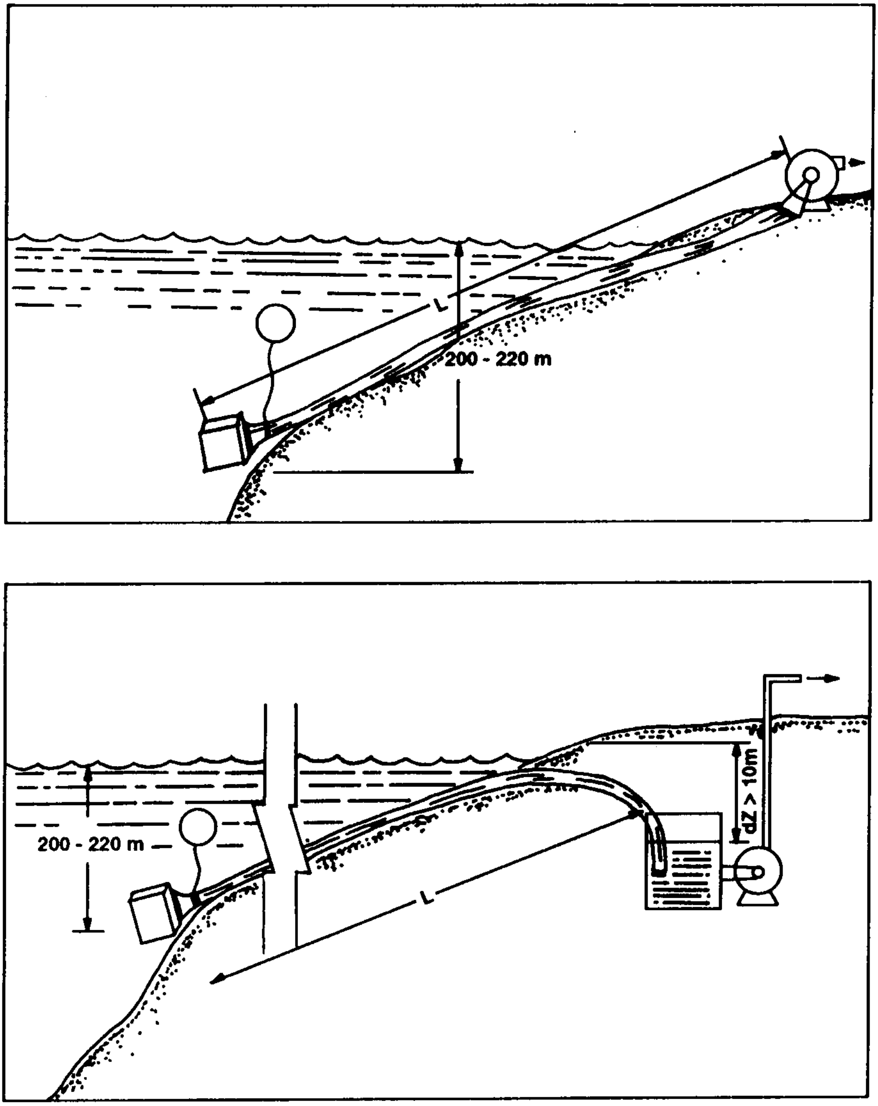

Figure 6. Schematic for presentation of the types of coolant water pumping to be employed

(a) Direct pumping (b) Syphoning and pumping

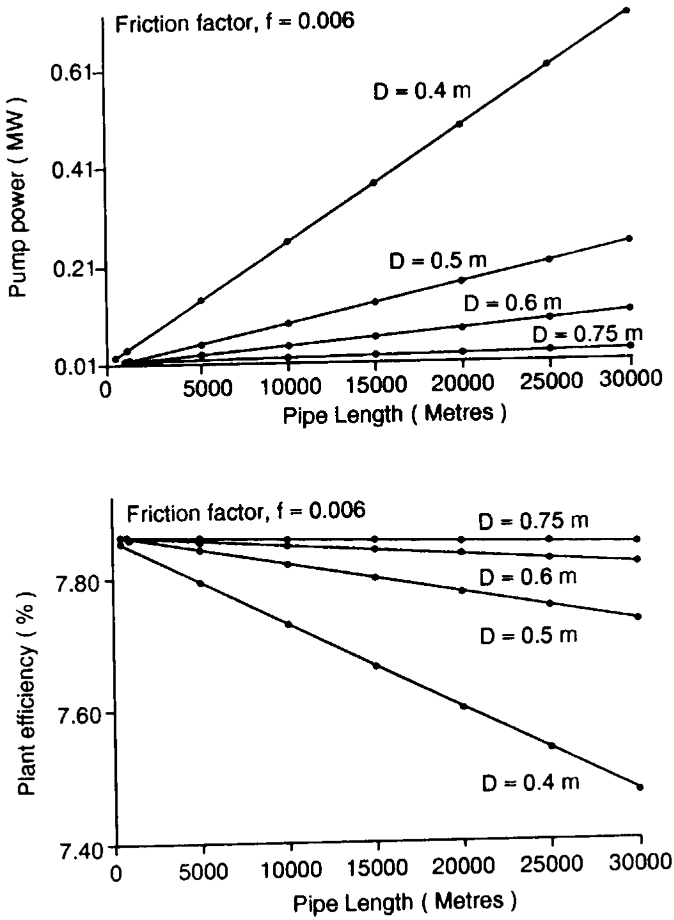

Figure 7 (a). Variation of pumping power requirement with pipeline for different pipe diameters; (b) Variation of power plant efficiency with different diameters and pipeline

Seawater can be siphoned through a long pipeline to the shore-based siphon tank. The required flow rate can be achieved by maintaining a desired static head (dZ) between the sea level and the level in the siphon tank. Diameter of the siphon pipe, pump suction and delivery pipes may be suitably chosen for the required continuous discharge. The pump can be fitted outside the siphon tank as shown and the water may be pumped to the power plant. The pump installation and maintenance are simple.

DESALINATION PLANT

As we have mentioned, coastal ocean spaces have little or no fresh water because of salt water intrusion into the land. In such cases a desalination plant would be extremely useful for supplying part of the fresh water required by the local communities.

A multistage flash (MSF) desalination plant may be coupled to OCSPPS. This dual purpose plant will generate fresh water in addition to the electrical power. There is an abundant quantity of seawater readily available at the discharge of the power plant condenser. A part of this water can be utilized as the feed water for the generation of fresh water in the desalination plant.

Figure 8 shows the schematic working of a two-stage desalination plant. The boiling point of the seawater can be lowered by decreasing the pressure. The feed water boiling may be effected at the temperature of 50-65° in the pressure range of 0.12-0.25 kg/cm^2 absolute.[5] Part of the seawater discharge from the power plant condenser is directly fed to the water vapor condenser of the desalination plant. The feed water gets preheated and its temperature is raised to about 38° by extracting the latent heat of condensation of the water vapor. The preheated feed water enters the evaporator stage-I (HTR I) and is heated by the part of the power generated at the power station. About 0.25 kg/cm^2 absolute pressure is maintained in the HTR I. The feed water evaporates at about 65°. Part of this vapor is utilized in heating the feed water in the evaporator stage-II (HTR II). Here the pressure of about 0.12 kg/cm^2 absolute is maintained wherein the feed water evaporates at about 50°. The vapor steam gets condensed here, and this distilled water is sent to the flash tank where the vapor gets separated and further condensed in the vapor condenser. The vapor steam from HTR II mixes with the vapor from HTR I and enters the vapor condenser at about 60°. The feed water passing through the condenser cools the incoming vapors and fresh water is generated in the distillate tank. The fresh water is drawn through the distillate pump. The vacuum is created by a mechanically operated air ejector (EJTR) which constantly drives out the air and the noncondensible gases.

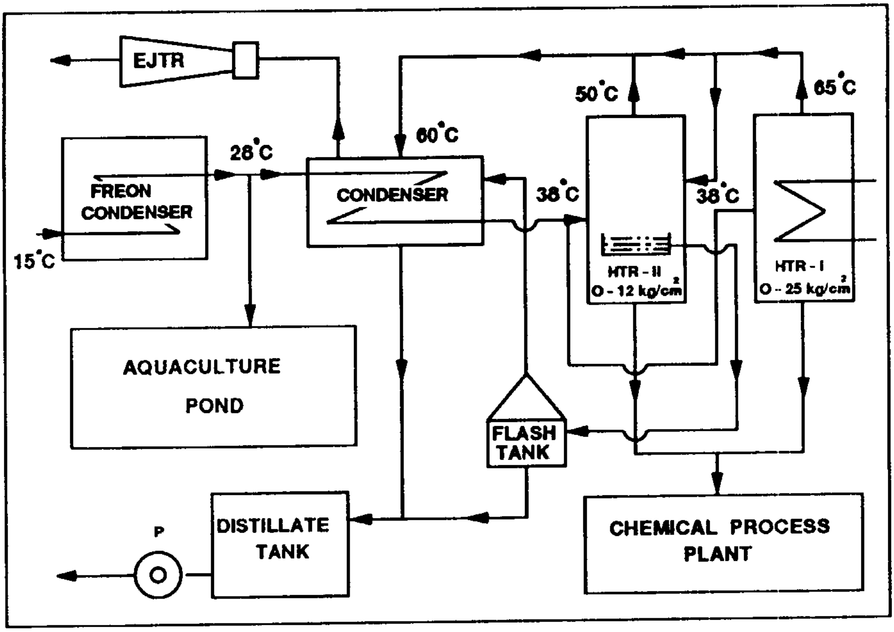

Figure 8. Schematic representation of a two stage flash desalination plant

Assuming about 80-90 kcal of heat will be required for generation of 1 kg of fresh water,[7] the equivalent power requirement for generation of 60 T/day fresh water (expected need for about 300-400 families) would be about 0.275 mW. This power can be drawn from the power generated at the power station. No additional power will be required for pumping the feed water as it is directly fed from the power plant condenser. A marginal power of about 5 kW can be made available for driving the vacuum pump and about 2 kW for the distillate pump.

Assuming the fresh water conversion factor of 0.3, the quantity of feed water for the generation of 60 T/day fresh water would be about 200 T/day. The balance of the seawater will be available for aquaculture and salt production. A small quantity will be required as make-up feed water to compensate for losses due to evaporation and spill over. On generation of fresh water, the remaining portion of the feed water in the evaporators is rich in brine and chemicals and can be utilized for extraction of marine chemicals. If more fresh water generation is required, this can be achieved by additional installtion of solar ponds or alternative heating.

AQUACULTURE

In the OCSPPS, for increasing efficiency we are pumping cold sea water from a depth of 200-250 m, available at the edge of the continental shelf. This water is rich in nutrients compared to that at the sea surface, and the water is free from pathogens because it is located offshore and at considerable depth. Suspended matter is minimal in this water. But for poor dissolved oxygen concentration, this water forms an ideal medium for aquaculture. Present day practices of aquaculture utilize sea surface water, which needs suitable filtering for use in aquaculture ponds. In recent years, aquaculture technology has been well developed in different parts of the world. Excellent overviews of the aquaculture practices in Asian countries can be found.[8,9]

Two Indian Examples

Along the Indian coast, vast areas suitable for aquaculture estimated at about 1.7 million hectares are available for aquaculture farms. The traditional system of shrimp farming is used in certain regions. More recently, the culture of brine shrimp artemia in coastal salt works has been taken in earnest. Herein we give a brief summary of the requirements for their culture in India.

Brine Shrimp Artemia in coastal salt works

The recent developments in aquaculture production of fish and shrimps have resulted in increased demands for *Artemia* cysts and adult biomass as a valuable source of live food.

The prerequisites for successful culturing of *Artemia* include a tropical/subtropical climate and proximity to a source of seawater. Salt ponds are ideal sites since they have well developed large condenser or evaporation ponds. The salinity requirement in the ponds prior to the introduction of *Artemia* is about 100 ppt. This should be maintained for a period of two months by regular intake of seawater. The temperature should not exceed 35°; ideal temperature is around 28-32°. Minimum water depth is 70-100 cm, and the water's pH should be around 8. The minimum size of the ponds could be 1 heactare and the maximum could be even up to 50 hectares.

During 1989-90, scientists from the National Institute of Oceanography successfully demonstrated the artificial culture of *Artemia* in a solar salt farm in Gujarat (northwest coast of India). *Artemia* introduced in a 20 hectare condenser pan yielded approximately 400 kg of dry cysts of *Artemia*, which is now being sold to shrimp hatcheries. There are immediate plans to increase production by introducing *Artemia* into larger areas (500 ha).

Solar salt works are suitable biotypes for the integrated exploitation of salt, *Artemia* and eventually fish or shrimp. In salt works, *Artemia* is only found in the evaporation ponds at intermediate salinity levels from about 100 ppt onwards up to

250 ppt. *Artemia* is not found naturally in salt ponds, but could be easily introduced and cultured.

It may be noted that *Artemia* feeds by filtering microscopic food particles. In doing so, it swallows algae, particulate calcium carbonate and calcium sulfate impurities from salt water. This process improves the quality of the salt produced.

The annual cyst requirement of various shrimp hatcheries in India is about 2 tp 2.5 T. With the commissioning of few more hatcheries in the next couple of years the requirement is likely to go up to 5 T.

The annual world production of *Artemia* is around 200 T. Most of the production is from San Francisco Bay, Great Salt Lake and recently from the People's Republic of China. Nearly 100 T of this output is consumed by Japan alone.

In OCSPPS, fertilizing the pond with organic or inorganic fertilizers is not required, as the water which is pumped from below 200 m is normally rich in nutrients and hence will trigger the growth of microscopic algae which form the food for *Artemia*.

Shrimp Culture

Of the 1.7 million hectares of land suitable for aquaculture, only 30,000 hectares are presently used for shrimp culture. A traditional system of shrimp farming has been in vogue in the states of West Bengal and Kerala for a long time. It essentially involves trapping juveniles in the fields adjoining the backwaters and estuaries with the incoming tides and allowing them to grow until harvesting. However, this has many drawbacks and the returns are low (400-600 kg/ha) when compared to scientifically managed shrimp culture system in which productivity is of the order of 2-6 T/ha. Lack of species selection, predation, and slow growth rates are the main reasons for this low return. Of about 55 species of shrimps occurring in the commercial landings in India, at least 15 are considered suitable for shrimp culture.[10] Of these *Penaecus monodon, P. indicus & P. merquiensis* assume priority because of the larger size attained, better survival in ponds and faster growth rates.

Seed of cultivable species of shrimps particularly that of *P. monodon* and *P. indicus* are collected in large numbers from the estuarine areas of West Bengal and Kerala. During seasons there is a flourishing 'seed industry' in these states. In addition, realizing the importance of shrimp culture and also realizing the fact that non-availability of seed is a hindrance in the propagation of shrimp farming, a few hatcheries have been set up along east and west coasts of India both in public and private sectors.

The Indian coast is blessed with good sunshine, the required water temperature (25-32°) and salinity (28-35 ppt) and other physicochemical parameters ideal for shrimp culture. An ideal prawn farm in Indian conditions would cover an area of 1-5 hectares and would have a water depth of 1-2 m. Larger ponds would have channels dug from the main gate area towards the periphery. The technology for scientific farming and establishment of shrimp hatcheries is available in the country. When coupled with systems generating power using differentials in thermal structure, shrimp culture would form an additional revenue source and also a source of employment for rural people. Systems using cooler subsurface water would bring up the nutrient rich waters and thereby create a productive environment required for the farming.

The OCSPPS supplies cold water with a salinity of 35 ppt. After getting heated in the condenser, the water is fed to the aquaculture ponds with a sufficient flow rate. Species which grow at about 35 ppt and around 30° temperature will be grown initially. Later, this water is fed into the salt ponds. Because of evaporation and containment of water, the salinity and temperature in the salt pond increase and the brine shrimp *Artemia* could be cultivated.

MARINE CHEMICALS

Almost all naturally occurring elements are present in sea water. The present scale of production of chemicals from sea water is very large. Common salt, magnesium metal, and its compounds, gypsum and potassium compounds and bromine, are presently recovered on an industrial scale.[11] The methods employed include absorption, evaporation, distillation, solvent extraction, ion exchange, precipitation, electrolysis, flotation and oxidation. In general, production depends on more than one of the above methods.

SALT PRODUCTION

Salt production is carried out by evaporation in separate ponds — concentrating ponds, lime ponds and crystalizing ponds. The largest area is occupied by concentrating ponds, where most of the water is evaporated. Iron hydroxide and calcium carbonate precipitate in this pond and the relative density of water increases from 1.027 to 1.16. It gets further concentration to a density of 1.21 gm/cc in the lime ponds, where gypsum is precipitated. The water is then passed on to carefully constructed harvesting ponds and further evaporated until its density increases to 1.26 and most of the NaCl is precipitated. The residual liquor, termed bittern, is further processed to produce other chemicals.

The seawater discharged from the OCSPPS and the desalination plant is about 19,000 T/day. Assuming 9 months of operation in a year, the total salt production will be about 120,000 T/yr at a recovery of 2.5%. The area required for the salt pans is estimated to be around 1,500 hectares.

Fairly sophisticated technologies are available for extraction of magnesium compounds, bromine and potassium compounds.[11] The seawater (0.13% Mg) is treated with a suspension of lime (CaO) and the magnesium is then precipitated out as hydroxide. The precipitated magnesium hydroxide is separated by filtration and converted to magnesium chloride which after purification and drying is reduced electrolytically to magnesium. The recovery this way is 85-90%.

The magnesium chloride produced initially will be utilized for constructing more solar ponds. Magnesium chloride gives better stability to the solar pond than sodium chloride.

Seawater is the world's principal source of bromine (66 gm/T). Using sulfuric acid, seawater is acidified to pH 3.5 and treated with a slight excess of chlorine. Bromine is then liberated according to the following reaction:

$2Br^- + Cl_2 \Leftrightarrow Br_2 + 2\,Cl^-$

The liberated bromine is stripped off from the water with a current of air and then reacted with a gas phase with SO_2. Hydrogen bromide is formed by the reaction as follows:

$Br_2 + SO_2 + H_2O \Leftrightarrow 2HBr + H_2SO_4$

This hydrogen bromide is then absorbed in a relatively small volume of water. The resultant HRr is treated with chlorine and bromine is distilled off with steam. The output is 2 x 10^4 T/yr.

OPEN CYCLE POWER GENERATION

The open cycle utilizes a low pressure flash evaporation chamber to produce steam, followed by expansion of the steam through the turbine and finally direct or indirect condensation by the coolant water. This type of plant works on the principle that the boiling point of water can be lowered by lowering the pressure on it. The warm water will boil in the flash evaporation chamber because of the partial vacuum. The steam generated thereby runs the turbine and generates power. If the spent steam is condensed by indirect contact with the cooling water, fresh water is a by-product of the power generation. The open cycle thermal energy conversion has a potential to produce up to 25 times more power than in a closed cycle plant. The parasitic losses are considerably low in the of the open cycle power generation. One disadvantage of the open cycle operation is the requirement of a large size turbine for power generation.

The power generated is will be utilized for power plant lighting and running pumps and other machinery, local lighting and household appliances, for the desalination plant, as the reserves for chemical processing plants and for future expansion.

A schematic representation of the proposed plan for utilizing the power generated is given in Figure 9. Assuming an average consumption of about 40kWh/month per consumer for lighting and household appliances, we may allocate about 0.35 mW for this utility which will serve about 2,000 families.[12] About 0.15 mW will be needed for total plant requirements. The balance, about 0.275 mW, may be utilized for the desalination plant to supplement the fresh water and the surplus of 0.225mW may be channeled for the chemical processing plant and as reserves.

POWER UTILIZATION

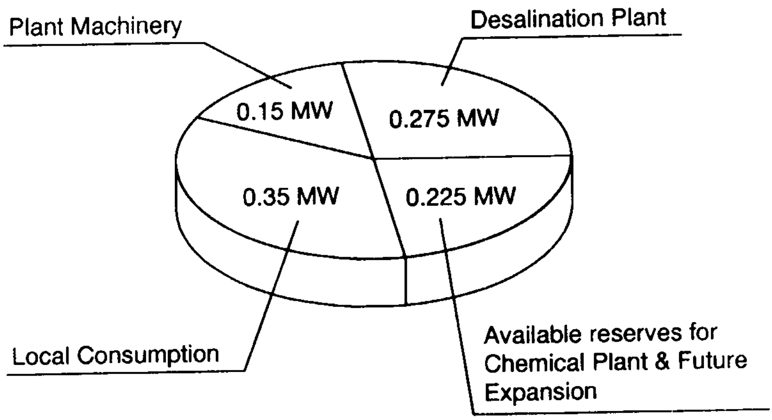

Figure 9. Utilization of the energy budget of the project

EMPLOYMENT POTENTIAL

The total project consisting of power plant with desalination and chemical plant, salt and aquaculture farm is estimated to employ about 600 persons in various departments. This will result in an indirect employment potential of 500-600 people in other areas like public offices, banks, schools, transport sector, hotels, shops, business institutions and small scale industries, etc. Thus, the project can develop a township with its own power and fresh water. The aquaculture products, minerals and chemicals bring in considerable revenue. A series of plants along the coast will help in the generation of employment and will certainly give socio-economic benefit to the country.

CONCLUSIONS

1. All the coastal wastelands in tropical regions can be brought under the scheme.

2. A series of ocean coupled solar pond power stations would be developed to provide power for the local communities.

3. A number of salt and aquaculture ponds could be set up.

4. Chemical processing plants in the coastal wastelands could be established.

5. Skilled and unskilled labors could be employed in salt and aquaculture farms. In addition, several technical persons for running the plants and for developing new research and development techniques are employed.

6. As these plants are spread over the length of coastline, the socio-economic impact on the local population is expected to be very high.

7. As an accessory, multistage flash desalination plants could be added to the plant for supplementing fresh water for the local population.

8. All the techniques outlined in this project are available. There is a need for scaling these technologies to suit the specific size of any given locality.

ACKNOWLEDGEMENTS

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APPENDIX

Details of Computation

Solar Pond Area:

Assuming an annual mean radiation energy of 5 kW-h/m²/day, an average value for Indian conditions, solar pond efficiency at 20% and power efficiency at 7.8%, the estimated area of the solar pond for generation of 1mW power would be approximately 33 hectares.

Power Plant:

For 1mW power generation, the quantity of heat supplied, rate of flow of the Freon, flow rate of hot brine and the cooling water and the pumping power requirements have been estimated. The Rankine efficiency and plant efficiency are also computed. The following assumptions have been made.

Turbine efficiency: 85%

Certrifugal pump efficiency: 85%

Friction factor for cooling water pipe: 0.006

1. Heat converted (Hc) into the mechanical work in the turbine is given by,

$$Hc = \frac{\text{Power output (heat units)}}{\text{Turbine Efficiency}}$$

$$= 1011800 \text{ kcal/hr} \qquad (1)$$

2. If Qr, the quantity of Freon required for the generation of 1mW power, enters the turbine in the superheated condition at 70° and leaves at 30°C,

$$Qr = \frac{Hc}{H_{70} - H_{30}}$$

where, H_{70} and H_{30} are the heat contents of Freon vapor at 70° and 30° respectively.

Then, Qr = 220,000 kg/hr. (2)

i.e. = 0.05 m³/sec (approx)

3. Cooling water and the Freon exchange the heat in the Freon condenser. The cooling water temperature is raised from t_2 = 15° to t_2 = 28° with Freon getting cooled from 30° to 20°. From the heat balance, the cooling water flow rate (Qw) is given by,

$$Qw = \frac{Qr \times (H_{30} - h_{20})}{(t_2 - t_1) \times Cp}$$

where, h_{20} is the heat content of Freon liquid at 20°.

Then, $Qw = 763200$ kg/hr (3)
i.e. $= 0.22\ m^3/sec$

4. Let Qb be the flow rate of hot brine entering the evaporator at $t_3=85°$ and leaving at $t_4=80°$. As a result Freon from 20° vaporizes at 70°.

$$Qb = \frac{Qr \times (H_{70} - h_{20})}{(t_3 - t_4) \times Cp}$$

i.e. $= 1988800$ kg/hr (4)
$= 0.56\ m^3/sec$

5. The Rankine efficiency (Nr) is given by,

$$Nr = \frac{H_{70} - H_{30}}{H_{70} - h_{20}}$$
$= 9.45\%$

6. Pumping Power (P) is kW is given by,

$$P = \frac{@ \times g \times Q \times H}{Np}$$

where, @ is the density, (kgm/m^3)
Q is flow rate in m^3/sec
H is the head in meter of water
Np is pump efficiency.

From this the power requirement for hot brine pump is,
Pb = 0.006 MW (5)

Power for the Freon pump is estimated at 0.001 MW (approx). (6)

Now, the cooling water pump power (Pw) varies with the pipe diameter and the pipe length. It is assumed that static head (Hs) is 2.0m, diameter of suction pipe (Ds) is 0.75m, diameter of delivery pipe (Dd) is 0.4m. The head (Hm) generated by the pump is given by,

Hm = Hs + Hf + Hd where, Hf is frictional loss
Hd is delivery loss.

Now,
$$Hd = \frac{Vd^2}{2g}$$
i.e. = 0.16 m

and
$$Hf = \frac{4fLVs^2}{2gDs}$$

Here the frictional loss in delivery pipe is neglected for its shorter length as compared to the suction pipe.

hence, $Hf = 0.0004 \times L$ m

$Hm = 2.16 + 0.0004\ L$

For the pipe length of 5000 m,

$Hm = 4.16$ m

Hence, cooling water pump power,

$Pw = 0.010$ MW. (7)

6. Power plant efficiency (Ng),

$$Ng = \frac{\text{Net output energy}}{\text{Input energy}}$$

Input energy is the total of (5), (6), (7) and heat input.

24

Practices, Possibilities and Impacts of Land Reclamation Activities in the Coastal Areas of Bangladesh

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ABSTRACT

Started as a coordinated effort in the sixties, land reclamation practices in Bangladesh involved mainly impoldering of existing saline coastal lands with the purpose to reclaim them for agricultural activities. Together with impoldering, closure works were also executed in moribund or secondary channels to stimulate natural accretion; the accreted lands obtained in this way were subsequently impoldered. Covering almost the entire coastal area of Bangladesh, in total, 4500 km dikes and 5200 hydraulic structures were planned to reclaim a land mass of 1.4 million hectares (ha). With respect to accretion possibilities, some areas of the central Meghna Deltaic Plain appear to have considerable possibilities; the high suspended sediments in the water column, and the high rate of accretion obtained by completed closure works indicate such potentialities. Land reclamation practices executed in this way, although, increased agricultural outputs considerably, are also responsible for their adverse effects on the coastal environment of Bangladesh, especially, in the siltation of drainage outlets and navigation channels.

INTRODUCTION

Coastal waters and adjoining land masses have been in economic use for a long time in the history of mankind. Some of the earlier uses were mainly directed at utilizing existing natural advantages in the exploitation of coastal waters for fish resources and in the promotion of communication, trade and commerce through ports and harbors built in estuaries. Subsequently, as economic and technological

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advances continued it became necessary to control nature for the advantages of mankind; to this end, exploitation of mineral resources, development of tourism and reclamation of coastal lands for agricultural and other economic purposes was undertaken. The type and level of exploitation of coastal resources developed differently in different countries depending on their technological advances and also on the level of prevailing economic infrastructures.

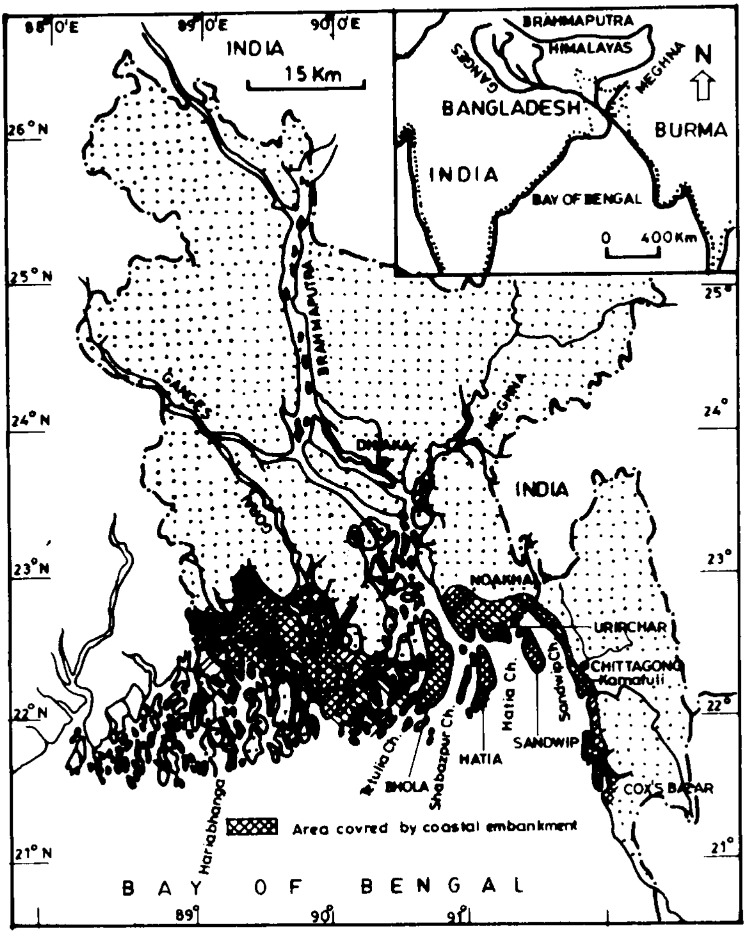

Figure 1. The coastline of Bangladesh and the Coastal Embankment Project

Bangladesh, having a less developed economical infrastructure, is far behind in the exploitation of its coastal resources. Studies of the coastal environment of Bangladesh and its resource potential have not received adequate attention; and the country lacks a comprehensive coastal zone management plan. Utilization of Bangladesh coastal areas is limited to agriculture, fishing, forestry, ports and harbors, tourism, salt production, industrial activities and recently, some ship breaking activities. This utilization and the field of activities are not much different compared to other countries, however, their developments were sporadic, resulting in conflict of interest and adverse impacts. Agriculture, which occupies most of the coastal space, is the main attention of this paper.

THE COASTAL ENVIRONMENT OF BANGLADESH

Located in a tropical climate, the majority of the coastline of Bangladesh represents the deltaic complex of the Ganges-Brhamaputra-Meghna (GBM) river system. Out of the total coastline, estimated to be some 654 km,[18] 380 km represents deltaic fringes connected to the GBM system (Fig. 1). The total inlets indenting the coastline number 26, 20 of these are connected to the GBM system and the rest are individual streams.[4] Barua described the entire coastline in three hydro-morphological units. The Ganges Tidal Plain in the west comprises areas from Hariabhanga river along Indo-Bangladesh border to the west bank of the Tetulia channel in the east. It represents older deltaic deposits of the GBM system and a major part of it is covered by nipa palm and mangrove forest (Fig 2).

The Meghna Deltaic Plain in the middle covers the area from Tetulia channel in the west to Sandwip channel in the east. The area is morphologically very active, with rapid migration of its channels and shoals.[5] Barua subdivided the Plain into fluvial, fluvio-tidal and tidal units; the Tetulia and the western Shahbazpur channels are fluvial, the eastern Shahbazpur channel and the western Hatia channel are fluvio-tidal, and the eastern Hatia channel and Sandwip channel are tidal.[4]

The north-south oriented Chittagong Coastal Plain comprises coastline from the Naaf River in the south to the Feni River in the south. This 274 km long coastline is divided into two zones, the area from the Naaf River in the south to Karnafuli River in the north is described as a wave-dominated sand coast and the coast northwards of Karnafuli River is an estuarine mud coast.[4]

The coastal area of Bangladesh is mostly mesotidal, except a small locality near Sandwip which is macrotidal.[4] The wave climate is moderate with near shore wave power as $0.586*10^7$ ergs/sec which is 18 times less than the Nile river coast.[19] The seasonal fluctuation of mean sea level along the Bangladesh coast measures 85 cm; and the coastal environment is affected by cyclone and storm surge activities, which occur mostly in the months of May and October-November. The sedimentary environment of the coastal area represents fine bed material ranging from coarse silt to fine sand.[4] The suspended sediment concentration varies from about 700 mg/l in the Ganges Tidal Plain to about 4230 mg/l, near the north-west coast of Sandwip.[2,4]

An overview is presented here regarding the principal economic activities other than agriculture. Marine fishing is one of the main economic activities; in 1989, total fish harvest was 233,000 tons, which, although it represents only 28% of the total catch, supports 0.5 million people, utilizing 52 trawlers and 3317 mechanized boats.[7] It contributes to about 5% of GDP and 6% to the national export earnings.[12] Natural mangrove forest occupies a significant portion of the coastal area of Bangladesh. The Sundarbans, which has been declared a reserved forest, occupies an area of 6,000 sq km (Fig. 2) in the Ganges Tidal Plain. Another small natural mangrove patch measuring about 75 sq km is located in the Chittagong Coastal Plain known as the Chakaria Sundarbans (Fig. 2). Apart from these natural mangrove forests, the Forest Department of Bangladesh made plans and implemented partial afforestation of 91,000 ha of newly accreted land,[18] mostly in the morphologically active Meghna Deltaic Plain. The purpose of this program is to stabilize newly accreted coastal land masses and to reduce the effect of storm surge damage. Bangladesh has two seaports, the Chittagong Port located in the east, in the mouth of the Karnafuli River and the Mongla Port located in the west, in the Pussur-Sibsa estuary (Fig. 2). In the period between July 1987 to June 1988 the cargo handled by Chittagong Port was 7.8 million tons and Mongla Port handled 2.9 million tons.[7] Bangladesh has yet to fully utilize its tourism potential, either its long sand beach along Chittagong Coastal Plain, particularly Cox's Bazar, or its natural mangrove forest, the Sundarbans. Industries in the coastal area are mainly concentrated in the port city of Chittagong and in Khulna near the port of Mongla. The main industries in Chittagong include refinery, still mill, fertilizer, cement, jute and textile mills, and pharmaceutical. Nearly 50 ship breaking units work along the coast of Chittagong.

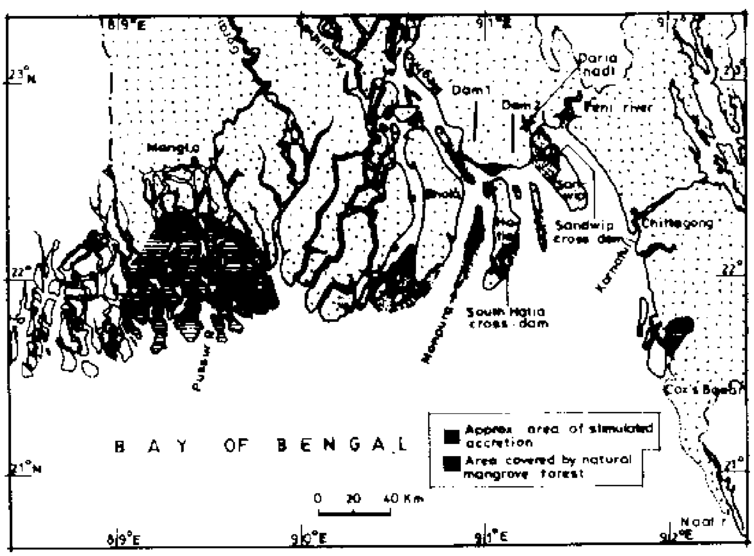

Figure 2. The coastline of Bangladesh, natural mangrove forests and accretion possibilities

ESCAP reports pollution hazards in the coastal waters of Bangladesh, resulting from industrial activities, fish processing, oil slick from ocean going vessels and ship breaking activities.[12]

LAND RECLAMATION PRACTICES

Land reclamation for the purpose of agriculture, as has been applied in Bangladesh, is characterized by two phases of activities. The first phase involves accretion promotion activities, if and when necessary; the technology mostly applied for this purpose was closure of moribund or secondary channels. Success of this measure was possible mainly because of high suspended sediments in the water column. The second phase involves prevention of saline water flooding these newly accreted lands or existing land masses. The technology applied for this purpose was to impolder the area by earthen dikes and drainage sluices.

Reclamation of coastal lowlands for agricultural purposes started in Bangladesh in the 1960s with the launching of a massive engineering project, the Coastal Embankment Project (CEP). This project, with its high initial benefits such as increased agricultural outputs and improved road communication, became very popular with the coastal population, and its two terms, 'Ari-bundh,' meaning cross-dam, and 'Beri-bundh,' meaning dike, became household names.

Cross-dams

Large scale closure — the cross-dam construction whose purpose is to promote accretion, started in Bangladesh in 1956-57. The first such dam was built over a dying branch of the Meghna river which is known as Noakhali cross-dam 1 (Fig. 3). This 13 km long dam was built by the East Pakistan Irrigation Department (now Bangladesh Water Development Board) and connected Ramgati to Noakhali mainland. This dam induced rapid siltation in an area of about 21,000 ha (Fig. 3). The second large cross-dam (Cross-Dam no. 2) was built in 1964, again in the dying Meghna river, but now more downstream, providing an accretion of 31,000 ha (Fig. 3). This 30 km long dam connected Char Jabber Island to the Noakhali mainland.

As part of the Muhuri Irrigation Project, a closure dam was built at the mouth of the Feni river in 1985 (Fig. 2).[8] Topographic surveys by the Land Reclamation Project indicate that the dam resulted in an accretion of about 4,000 ha of new land. Two small dams have been built in Monpura Island (Fig. 1), one in 1978 and the other one in 1989; together they resulted in an accretion of 200 ha of new land. In 1982, as part of the accretion trial programme, an older branch of the Noakhali Khal, the Daria Nadi was closed, which induced siltation in an area of about 200 ha. Due to this dam, the channel cross-sectional area reduced by about 650 m^2 per year.[1]

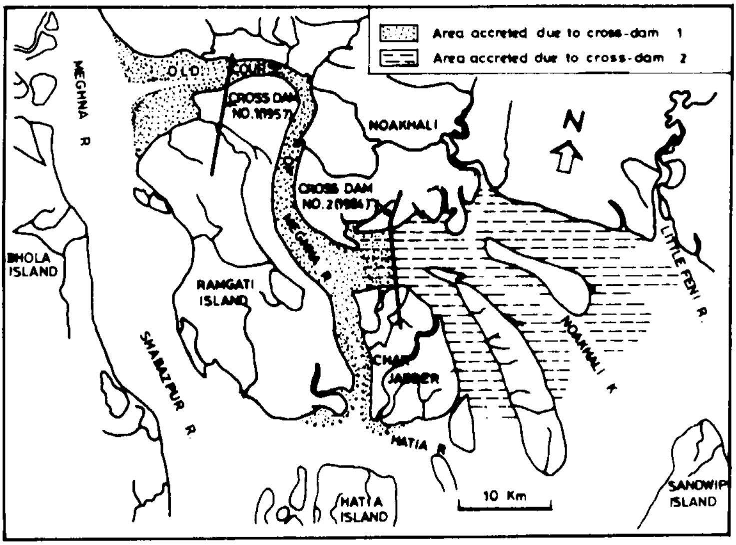

Figure 3. Accreted land masses due to cross-dams 1 and 2

Impoldering

Existing or dam-induced newly accreted areas are then impoldered. This is materialized with the help of earthen dikes and drainage sluices, the purpose being to create so called 'polder' units which would act as individual water management units.[16] Small scale closures of channels are also an integral part of impoldering with the view to concentrate scattered drainage flow in few large channels. The earthen dikes prevent either import or export of overland water flow, specially saline water import and fresh water export. The height of the dikes varies from place to place depending on the local high tide level and degree of exposure of the area, and varies between 3 to 4 m for sea dikes and 2 to 3 m for interior dikes. Figure 4 shows the eroded outcrop of an earthen dike in Hatia.

The drainage sluices are massive concrete structures which are built to ensure gravity drainage during excess rainfall through vents, and are provided with flap gates in the sea side which close automatically as water level outside the polder becomes higher than inside level due to tide or flood. Figure 5 shows a 10 vent sluice in southern Bhola.

For various reasons, such as drainage and topography, the entire coastal belt was divided into series of polder units. In all, 4500 km of dikes and 5200 hydraulic structures were planned to reclaim a land area of 1.4 million ha.[16]

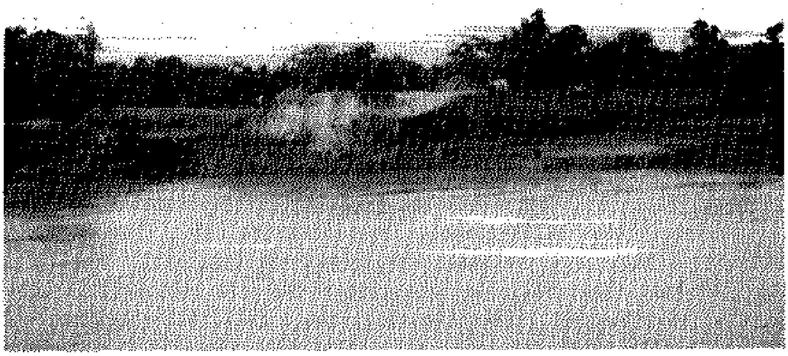

Figure 4. Eroded outcrop of an earthen dike in Hatia

During all those polder constructions, a very crucial issue was not scientifically addressed. This question involves the accretion level at which impoldering can start. LDL[15] set the impoldering level based on the suggestions and experiences of its field engineers; the result is serious drainage congestion and siltation of navigation channels. Based on siltation studies of the Feni dam accreted area, Barua suggested zoning of coastal areas depending on coastal configuration and hydro-sedimentological behavior and to postpone impoldering until siltation reaches up to about 0.5 to 1 m above mean high water level.[3]

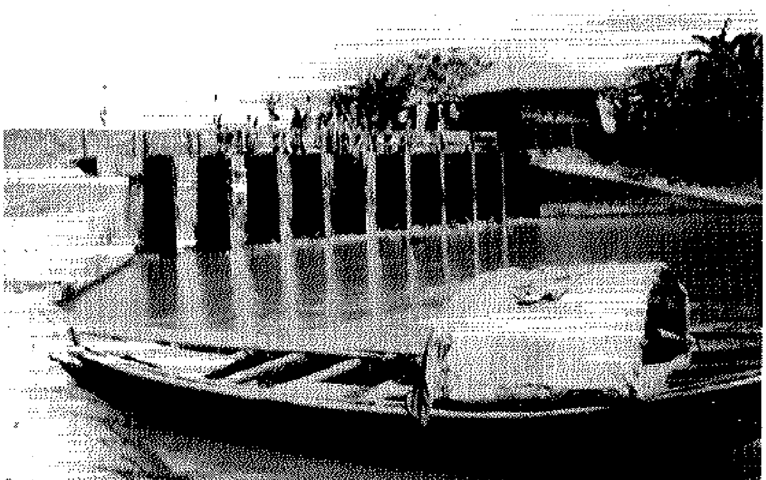

Figure 5. A 10 vent drainage structure in southern Bhola

ACCRETION POSSIBILITIES

Of the three hydro-morphological units, some areas of the Meghna Deltaic Plain present a promising location of accretion possibilities, particularly because this area is the present mouth of the GBM system (Fig. 1) which carries a huge sediment load. The Ganges Tidal Plain, representing an abandoned delta, is mostly stable and covered by mangrove forest. The Chittagong Coastal Plain, particularly the coast southwards of Karnafuli river, is mostly wave dominated.

Several factors have to be considered to investigate accretion potentials. The first is the nature and amount of sediment delivery (fluvial or marine) in the system. The fluvial sediment delivery from the GBM system, estimated to be some 1670 million tons annually,[17] mostly appears to be lost in the Bay of Bengal;[11,15] although this finding is true in general, the rapid channel migration of the Meghna Deltaic Plain and a very slow seaward progradation of the delta indicate that there exist certain accretion possibilities if situations can be created for sediment catch.[5] Barua also indicated import of marine or recirculated GBM sediments, along tidally active channels of the Meghna Deltaic Plain.[2]

The second factor is the amount of sediment primarily transported in the water column and the resulting rate of siltation. Barua derived siltation rate equations based on studies in the newly accreted area downstream of Feni dam.[3] The siltation rate,

$$d_t = d_0 \exp[-q(t-t_0)]$$

Where,

$t-t_0$ = time in years after closue,
d_0 = initial depth of water before closure (m),
d_t = depth of water after a time period t (m),
q = a coefficient.

The value of the coefficient, q, depends on the suspended sediment concentrations (SSC) and grain size distribution of the bed material. For Feni Dam area the value of q is 0.78, for south Hatia area it is 0.43 and for south Bhola area it is 0.023. This relation shows that the siltation near the Feni Dam area reaches mean high water (MHW) level in about 2 years, the south Hatia area reaches MHW in about 4 years, and the south Bhola area takes more than 50 years to reach the MHW level. This difference is due to variation in the SSC and mean grain size; for example, the Feni Dam area represents a SSC of 4230 mg/l and a d_{50} of 30 μm, and the south Bhola area represents a SSC of 126 mg/l and a d_{50} of 60 μm. The relation indicates that tidal channels of the Meghna Deltaic Plain have considerable accretion potentials.

To investigate the potential for land accretion and to explore various possibilities, the Bangladesh Water Development Board launched the Land Reclamation Project in 1978 with technical assistance provided by the Netherlands International Cooperation Foundation. This project, covering the entire Meghna Delta region, collects hydro-sedimentological data with its survey vessel M.V. ANWESHA. The studies executed by the project indicate high accretion possibilities in the region.[13] It completed feasibility studies of two projects, the Sandwip Cross Dam Development Scheme and South Hatia Cross Dams Scheme.

The Sandwip Cross-Dam Development Scheme (Fig. 2) involves making a 22 km long dam connecting Sandwip island to the Noakhali mainland.[9] This dam would develop and reclaim 36,000 ha of land.

The South Hatia Cross-Dams (Fig. 2) comprise two dams, one with a closure gap of 1.5 km and the other with a closure gap of 2.5 km. These two dams would reclaim and develop 17,000 ha of land.[10]

IMPACTS OF LAND RECLAMATION

Land reclamation works disturb the existing natural system of balances among different factors. These are the existing land-water system, aquatic ecosystem and forest ecosystem.

The adverse effects created by the disturbance on the land-water system include accelerated erosion at undesirable places, undesirable siltation patterns, siltation of drainage outlets and water logging, loss of water dependent sports and trade and commerce depending on navigation. Erosion of existing lands may take place if the reclamation measure blocks a drainage channel, forcing its flow through other outlets and increasing its section through erosion. It may also result by its influences on the tidal response of the system by increasing its tidal ranges.

Although studies indicate otherwise, the government of Bangladesh has not undertaken the construction of Sandwip cross-dam and requested further studies, partly due to the fear that it may cause erosion of Hatia and Bhola islands due to its assumed effect on river discharge. Studies also indicate that the dam will cause increase in tidal range primarily during initial stages after completion of the dam. This will happen due to increased reflection of the tidal wave.[9]

Undesirable siltation in the form of siltation of drainage outlets and resulting water logging of agricultural fields, and siltation of navigation channels are some of the unavoidable and serious consequences of land reclamation activities. Here two cases will be demonstrated resulting from land reclamation activities such as cross-dam construction and polder development.

The two cross-dams built in Noakhali have caused siltation of their several drainage outlets, causing water logging and affecting agricultural yields in an area of about 150,000 ha. The primary cause in this case is the progradation of coastline due to continued siltation which took place by about 30 km.[1] In Figure 6, the coastline progradation and the resulting reduction in channel flushing capacity have been demonstrated schematically.

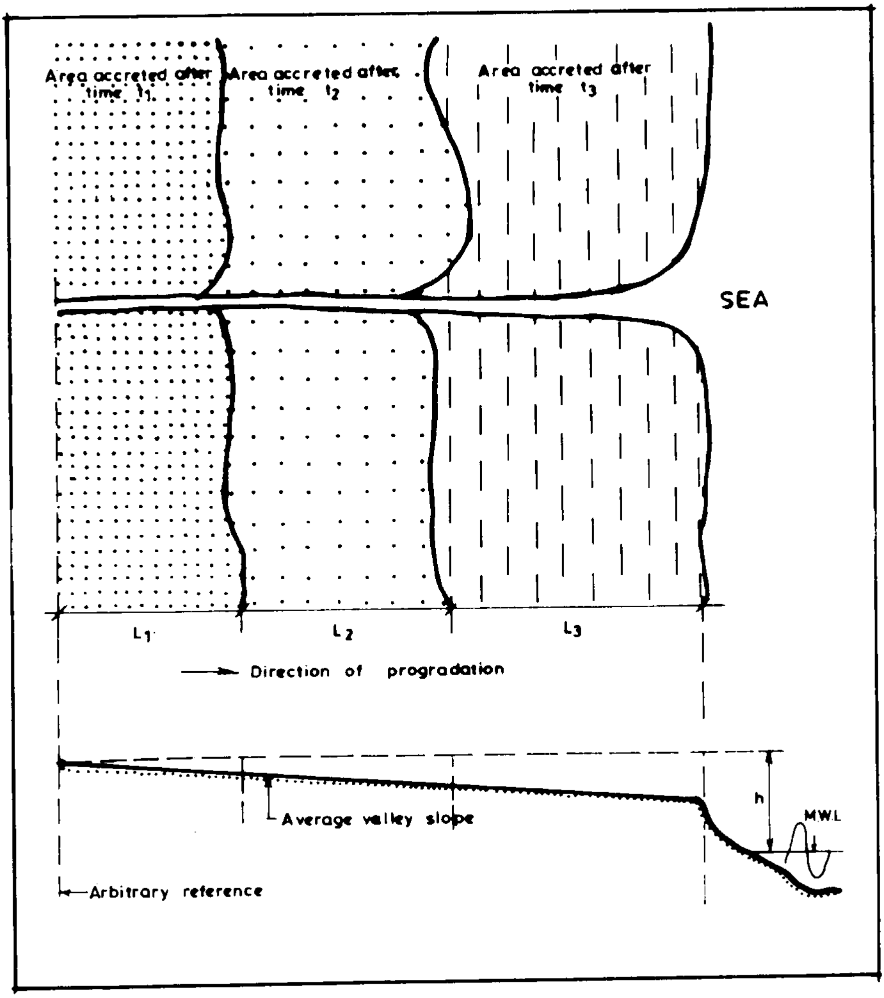

Figure 6. Reduction in flow gradient due to shifting of coastline by siltation

During the three periods of progradation, t_1, t_2 and t_3, the progradations are L_1, L_2 and L_3. As the drainage base, the mean water level (MWL) remains the same, h is constant from the reference level. The bed level gradient changes as,

after time t_1, the bed level gradient is h/L_1,
after time t_2, the bed level gradient is $h/(L_1+L_2)$,
after time t_3, the bed level gradient is $h/(L_1+L_2+L_3)$.

After every time period, the bed level gradient is decreased. If we recall the Chezy relation of uniform flow which is,

$V = C\sqrt{hI}$,

Where,
V = the mean flow velocity (m/sec),
C = Chezy coefficient,
h = water depth (m),
I = bed level gradient.

The relation indicates that, as the bed level gradient is decreased due to continued siltation, the flushing velocity decreases according to the square root of the bed level gradient. This is the cause of deteriorating gravity drainage resulting from foreland accretion.

In Figure 7, the siltation of channels has been demonstrated as a result of impoldering activities. Before the closure, a tidal prism, V, enters the drainage channel. After placing sluices, closures or dikes, the tidal prisms, V_1, V_2, V_3, V_4 and V_3 are prevented through the channels. Therefore, the new decreased tidal prism entering the main drain becomes,

$V - (V_1+V_2+V_3+V_4+V_5)$.

There exists an equilibrium relationship between the channel cross- section and tidal volume. For the tide dominated channels in the Meghna estuary, Barua and Koch found a relationship,[6]

$A_{mwl} = 58*10^{-6}*V$.

Where, A_{mwl} is the cross-sectional area in m^2 below mean water level and V is the average tidal volume in m^3. This relationship shows that the reduction in tidal volume induces siltation of channels reducing the channel cross-sectional area, in an attempt to restore the equilibrium relationship.

Siltation of drainage channels is one of the main causes of drainage problems in the coastal area of Bangladesh. Barua discussed this problem extensively for the Noakhali area where drainage problems are primarily caused by construction of cross dams 1 and 2.[1] The siltation also causes problem to navigation. Farleigh has shown that coastal embankments are one of the main causes of siltation of the Mongla Port entrance channel.[14] The channel section, measuring some 5576 m^2 around 1970, when costal emabankment construction started, became 4645 m^2 by 1975.

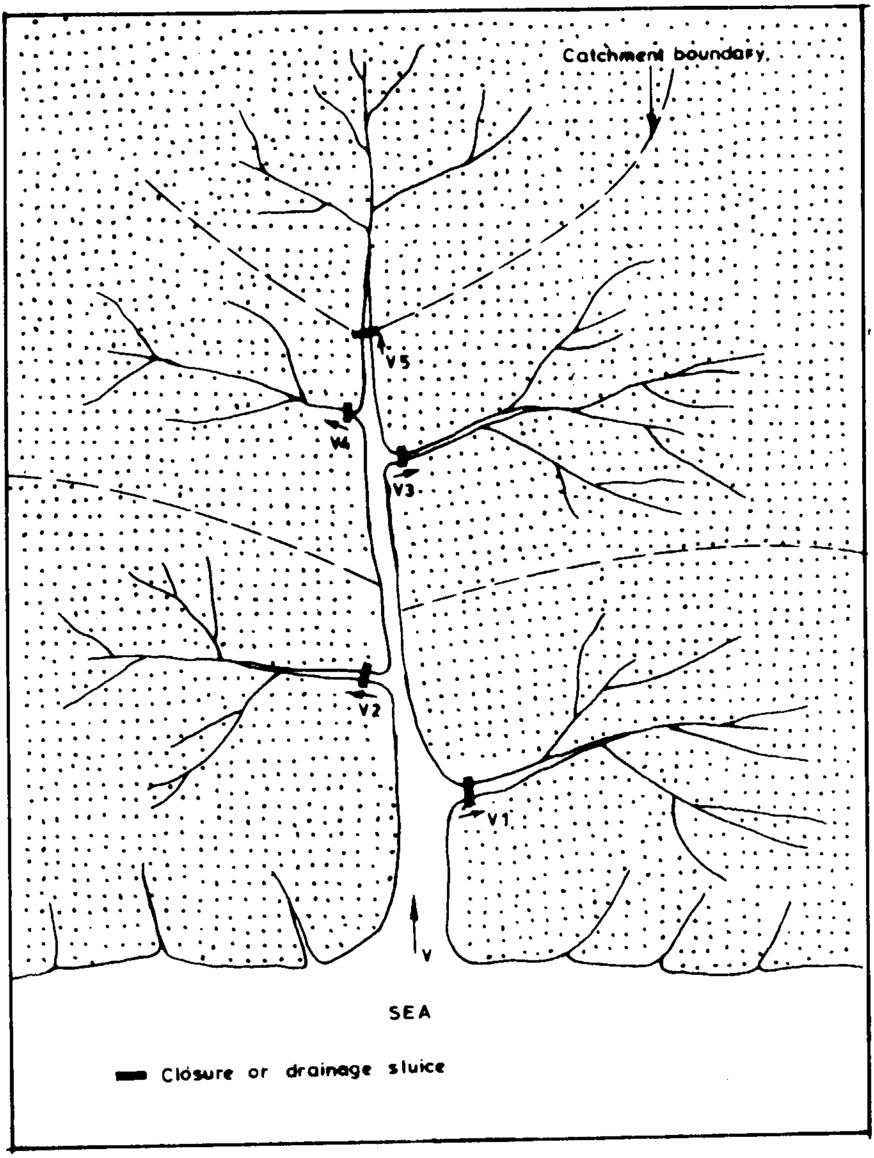

Figure 7. Channel siltation as a result of impoldering

The disturbance of the aquatic system and its adverse effect on the socio-economic environment, including loss of fishing grounds, blocking of the migration routes of fish populations, disturbing the existing salt-water balance, disturbing the existing sediment water balance, and loss of nursery grounds for juvenile fishes, has recently received attention from different quarters and is being documented accordingly.[9,10,12]

CONCLUSIONS

Land reclamation activities, executed extensively in the coastal area of Bangladesh, were materialized with the help of earthen dikes and drainage structures. In addition to these already executed activities, some areas of the Meghna Deltaic Plain indicate further possibilities of land accretion. The activities, although they have increased agricultural yields considerably, have also had adverse effects on drainage and navigation.

ACKNOWLEDGEMENTS

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Land Reclamation with Waste and Its Use in the Port of Osaka

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ABSTRACT

Since 1958, the development of man-made islands, such as Osaka-Nanko and Osaka-Hokko, has been a priority at the Port of Osaka. To create a modern port embodying a new concept, the harmonization of port and urban facilities must be considered. A modern port is an important factor in Osaka's economic foundation, along with residential areas and recreational facilities which are closely related to the citizens' daily lives.

The reclaimed islands mentioned above are also used as urban waste disposal sites. To improve the urban environment, as when purifying the river water, the soil containing organic sludge is dredged and disposed of on an island under reclamation. On islands used as waste disposal sites, infrastructures including high-grade sewage treatment plants and incineration plants are built to improve the environment for the citizens.

This report will focus on several aspects of the relationship between port development and waste disposal at Osaka Port.

FOREWORD

The Greater Osaka Region, radiating 50 kilometers from the center of Osaka city, with a population of 16 million, and producing 2% of world GNP in 1987, is the second largest metropolitan area in Japan. The Port of Osaka has been massively promoting port development with state-of-the-art technology as an important base for economic activities of the city and its hinterland. At the same time, it has been

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creating new harbor space in harmony with the city by constructing manmade islands with housing and recreational facilities built to meet the demands of the citizens.

To improve the city's environment, reclamation work has been promoted to dispose of dredged soil, comprising organic sludge from the estuaries, sludge from sewage, and refuse. Futhermore, the reclaimed land created from the waste is to be used as a space to install infrastructures indispensable for a clean and comfortable living environment for the citizens, such as a sewage system and incineration plants. This paper will cover the methods of reclamation from waste disposal at the Port of Osaka and the use of the reclaimed land especially at North Port.

WASTE DISPOSAL PLAN IN OSAKA CITY

The issue of waste disposal in large cities

Before the industrial age, a recycling system which generated no waste was firmly established in the agricultural society of Japan, where barnyard manure produced from piled and decomposed straw and dung was reused. However, higher living standards and the development of economic activities have increased the amount and types of waste generated in urban areas. Consequently, it is impossible to dispose of waste naturally, so the issue of waste disposal has emerged as a task we have to tackle.

Securing a suitable final waste disposal site within the downtown area has become a very serious urban problem today, so as not to pollute the environment by illegal dumping in the mountains and rural areas. Thus, to develop economic and cultural activities in urban areas and to increase even further the standard of living, the establishment of methods to preserve resources and energy while properly disposing of waste generated by consuming these resources and energy is required.

Quantity of waste generated in the City of Osaka

In Osaka, like many other large cities, the amount of waste has been increasing yearly. The waste generated by the city is categorized as follows: refuse from households is "ordinary waste," waste generated through the operation of public facilities such as water supply and sewerage system is "public industrial waste," waste produced by private sector activities including manufacturing is "private industial waste," soil and sand from civil and construction works are "construction waste," and waste from eliminating organic sludge, and from dredging needed to maintain and develop the port and estuaries is "dredged soil." The breakdown of waste generated in the city in 1989 is shown in Figure 1: ordinary waste comprises 15.2%, public industrial waste 34.2%, construction waste 22.1%, dredged soil 28.5%. Ordinary waste has increased 2.5 times in the last 25 years, amounting to 2.06 million tons/year in 1989 (Figure 2).

(unit : tons)

ordinary waste 2,056,400 (15.2%)	industrial waste 4,638,000 (34.2%)	construction waste 3,007,600 (22.1%)	dredged soil 3,865,400 (28.5%)

note : specific gravity of dredged soil = 1.4

Figure 1. Breakdown of Waste Generated in Osaka City

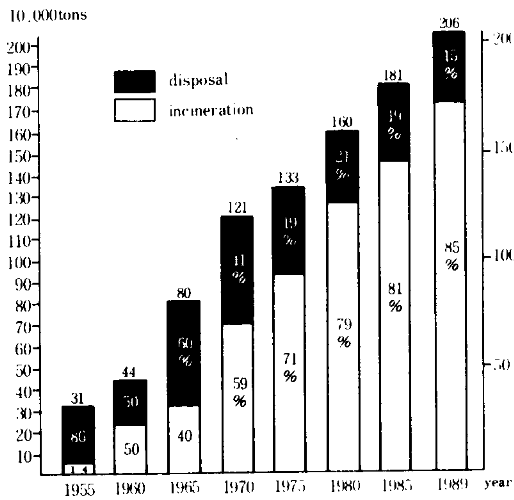

Figure 2. Change in Ordinary Waste Generated in Osaka City

Waste disposal plan in the City of Osaka

The basic concept of waste disposal is to restrain from generating waste, to utilize waste effectively once it is generated, and to reduce its amount and process it when it is necessary, while attempting to preserve the environment and to restore nature damaged by waste as soon as damage occurs.

With regard to waste disposal in Osaka city in 1989, about 85% of ordinary waste was reduced by 74% by incineration and the ashes left were used in reclamation. About 59% of the entire industrial waste was available to reuse and the rest was disposed of. Approximately 70% of land surplus soil was reused and the rest was used as landfill. All the dredged soil was reclaimed.

As Osaka's city area has urbanized, it has become more difficult to find a final waste disposal site in the inland area. Therefore, construction of final waste disposal sites in the form of man-made islands within the port area was started (Figure 3). Final waste disposal sites in Osaka Port are the North Port North District (209 ha) where construction work was started in 1972, and the North Port South District (288 ha) where construction began in 1977. The North Port North District accepted 28.6 million m³ of waste during 14 years from 1973 to 1987 when it was completed. The North Port South District began to accept waste in 1985 and is designated to dispose of 50 million m³ within a 10-year span until 1995 (Figure 4).

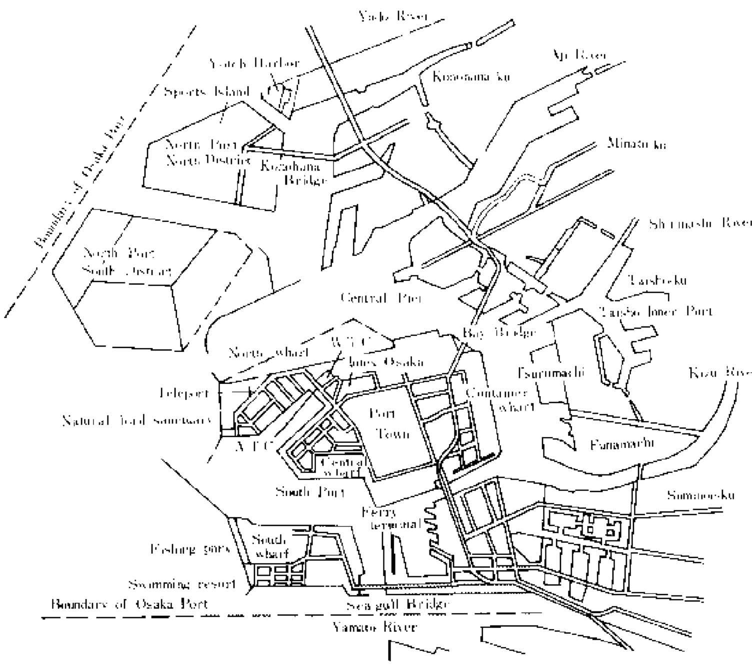

Figure 3. Location of Waste Disposal Site (North Port)

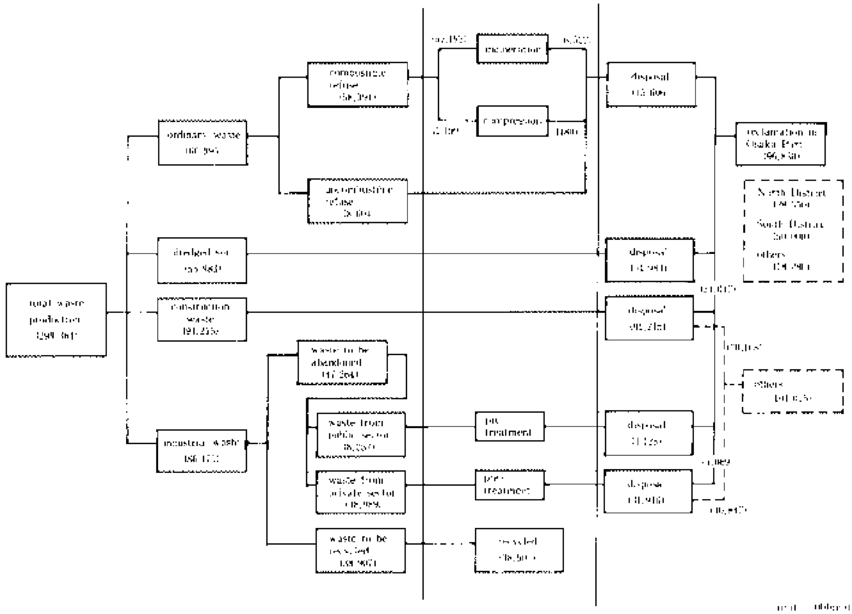

Figure 4. Flow Chart of Waste Disposal Plan (1974-1995)

CONSTRUCTION OF FINAL WASTE DISPOSAL SITES

Securing waste disposal sites in the sea

In Osaka city, where land is limited, effective use of urban space has to be maintained in order to accommodate and keep abreast of the energetic activities of the city and provide a comfortable living environment for its people. The same can be said for the waterfront area in the Port of Osaka where there are many land use requirements. One of the most urgent requirements in the waterfront area is to develop modern port facilities to support the economy in the Osaka region. In recent years, there have been demands for increased berth capacity to cope with the increasing size of container vessels and for the development of new distribution facilities in response to changing trade structures and transportation systems. At the same time, mercantile and office functions must expand to support international trade, which is a source of more diversified and advanced port activities.

In addition, facilities are required to enhance advanced information systems and allow the development of advanced technology because these are necessary to match the demands of today's urban areas.

Further, to ensure a comfortable and affluent lifestyle for the local people, a large-scale residential development offering a good living environment along with parks, waterfront recreation areas and marine leisure facilities must be developed. Moreover, adequate waste disposal areas, the main subject of this report, must be secured.

To ensure the effective use of land for the various requirements of the port and harbor districts, the City of Osaka has been studying the appropriate size and layout of the port facilities, which will provide the necessary basic facilities of a calm water area including the waterways, enough water depth for terminals and container berths and a comprehensive, streamlined distribution system.

The City has been calculating the estimated volume of waste to be disposed of in the next 10 years and the estimated area of land required to support planned urban activities. An environmental assessment has also been conducted and the scale and location of reclaimed land has been studied. Clearly, many aspects are examined before finalizing a socially acceptable waste disposal site in the sea.

Outline of the final waste disposal sites in the sea

A waste disposal site in the sea is an area enclosed by a series of seawalls. Because the types of waste to be disposed of there are so diverse, steps must be taken to use disposal methods appropriate to each waste, to prevent secondary pollution, and to create subdivisions in consideration of future land use.

Final waste disposal sites in the Port of Osaka, the North Port North District and South District, are divided into first, second, and third subdivisions as shown in Figure 5. The first subdivision holds ordinary waste, of which the characteristics of subsidence is hard to estimate at a fixed rate, and where secondary pollution is prone to occur after the reclamation. Also present are industrial waste and sludge from the water supply and sewage system. After reclamation, this land will become a green zone, in conformance with the plan to make a green belt along the west side of the waterfront of Osaka port. The second and third subdivisions hold land surplus and dredged soil, so that the land is available for general use after the reclamation.

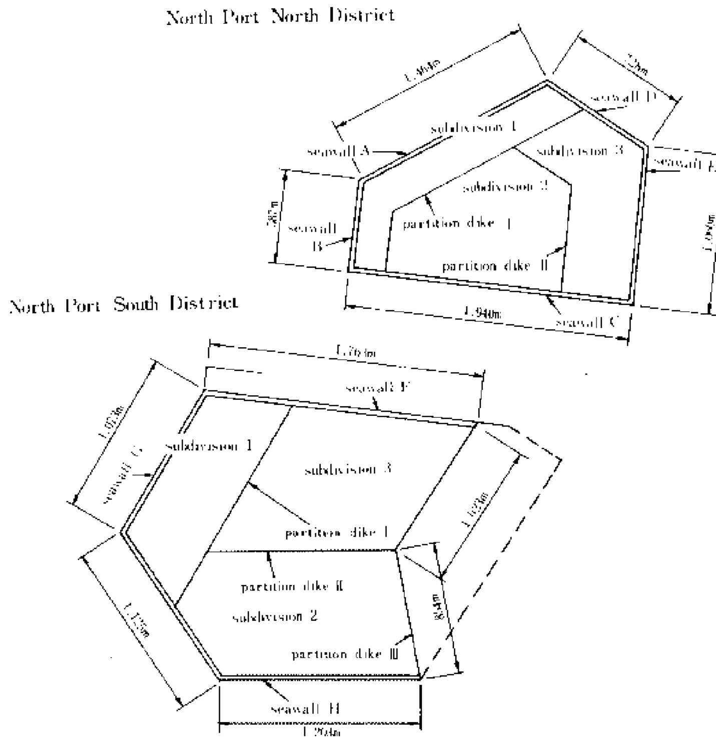

Figure 5. Waste Disposal Site of North Port

Waste was not carried in by land to the North Port North and South Districts in the beginning of the reclamation, so facilities to unload waste and also to prevent secondary pollution from occurring were installed. Table 1 shows the outline of the waste disposal sites in both districts.

Table 1

Outline of Waste Disposal Sites in North Port

item	North District	South District
area	209 ha	288ha
capacity of waste accepted	28.55 million m³ subdivision 1: 9.11 million m³ subdivision 2-3: 19.11 million m³	50 million m³ subdivision 1: 11.69 million m³ subdivision 2-3: 38.31 million m³
total length of seawalls	seawalls 5.881 m partition dikes 3,657m	seawalls 5,164m partition dikes 4,578m
kind of waste accepted subdivision 1 subdivision 2 - 3	ordinary waste, sludge from water supply and sewage systems dredged soil, construction waste	
period of construction	1972 - 1977	1977 - approximately 1994
period of acceptance	1973- 1987	1985 - approximately 1995
total cost	46.9 billion yen	107.6 billion yen
present status	100%	82% (as of the end of March. 1989)

Structure of seawalls

Boundary seawalls

When planning seawalls for general reclamation, one of the main things to be assessed is the fundamental functions of a seawall, including its strength against the force of waves, its soil pressure, the credibility of construction, and economy of construction.

In the case of seawalls for reclamation using waste, the following two items must be added in the assessment:

i) To secure vast enough space for filling of waste in a certain area.

ii) To secure water tightness of seawalls.

From the viewpoint of i), construction methods generating less dredged soil, such as the sand compaction pile method, are recommended for the seawalls constructed on very soft ground conditions. Dredged soil is generated as waste during the ground improvement when the excavate and replacement method is used. Table 2 shows the outline of the seawalls in the North Port North and South Districts. The soil of the area around the seawalls, approximately 20 meters deep from the seabed (-3 to -8 m) is composed of very soft alluvial clay which is unique to Osaka, and a diluvial formation lies below. Therefore it is essential to locate the foundation in this diluvial formation when structures are constructed in the port of Osaka. For this reason, sand compaction pile is placed as the foundation so as not to generate dredged soil. Every seawall is equipped with back-filling of 20 meters width to secure water tightness. Major types of seawalls and partition dikes are described in Figures 6, 7, 8, 9, and 10.

Table 2

Structure of Seawalls in North Port

seawall	type	improvement of foundation grounds	designed crown height (D.L.)	water depth of seafront (D.L.)	breadth of back fill (from the face line) (m)	total length (m)
A	composite dike	sand drain	3.5	−2	20	1,000
A	double-sheet piles wall	sand compaction piles	3.5	−4	20	586
B	composite dike	excavation of seabed and displacement by sand sand compaction piles	4.3	−4	20	586
C	coupled batter piles	sand compaction piles	3.3	-1	20	1,993
D	caisson	excavation of seabed and displacement by sand	- 1	20	780	
E	existing breakwater (caisson) reinforced	sand compaction piles	6.7	- 10	20	1,060
partition dike I	double-sheet piles wall	sand drains	4.9	- 3	-	2,060
partition dike II	double-sheet piles on embankment	sand drains	5.7	-2	-	1,083
F	caisson	sand compaction piles deep mixing	5.7	- 1	20	1,293
G	upright wave dissipating caisson	sand compaction piles	6.8	- 6.3	20	2,198
H	upright wave dissipating caisson	sand compaction piles	6.8	- 6.3	20	1,203
part-tion dike I,II,III	double-sheet piles wall	sand drains	5.0	-0.5-3.0	-	1,877 I 1,586II 1,115III

I) Seawall B (Figure 6)

The seawall is composed of composite dikes, with wave dissipating blocks at the forefront. As a foundation, sand compaction piles are set to the deeper side and to the upper side, the layer of very soft clay, the method of excavation of seabed and displacement by sand is taken.

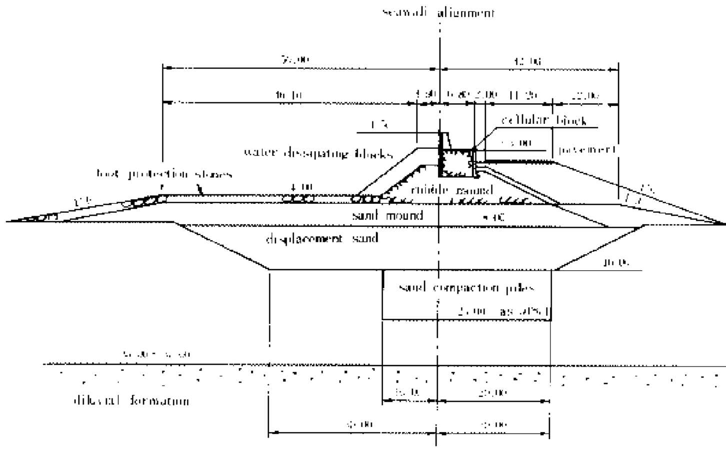

Figure 6. Cross Section of Seawall B (unit: m)

II) Seawall C (Figure 7)

Facing waterways, this seawall has the structure of steel pipe sheet pile with battered piles, so that the revetment is easily accessible and port facilities may be installed in the future. The foundation is improved by sand compaction piles.

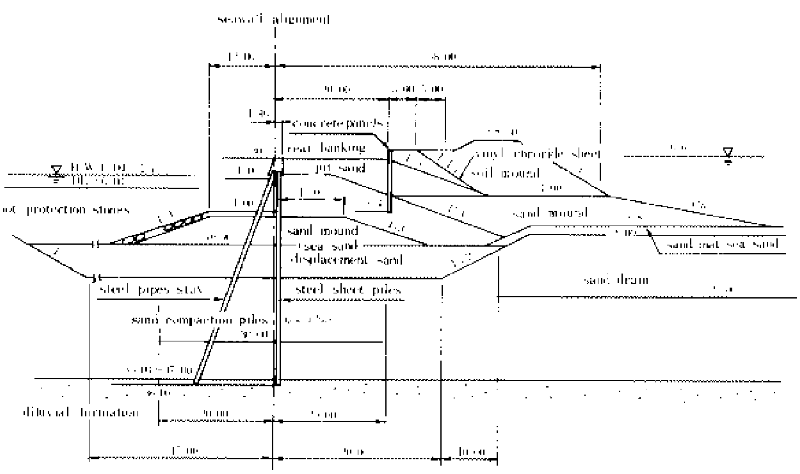

Figure 7. Cross Section of Seawall C (unit: m)

III) Seawall G (Figure 8)

Since this seawall is subject to direct waves from outersea in winter, the wave-dissipating caisson type was adopted and its foundation was improved by sand compaction piles.

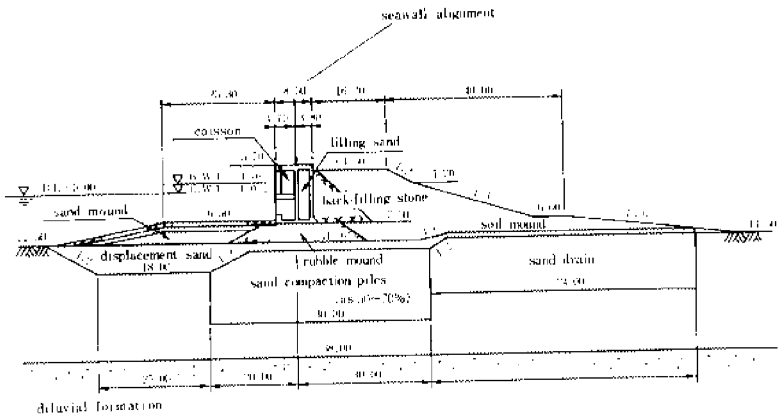

Figure 8. Cross Section of Seawall G (unit: m)

IV) Partition Dike (1) (Figure 9)

As various kinds of waste are filled in the North Port North and South Districts, partition dikes composed of doublesheet pile walls are placed to divide the site.

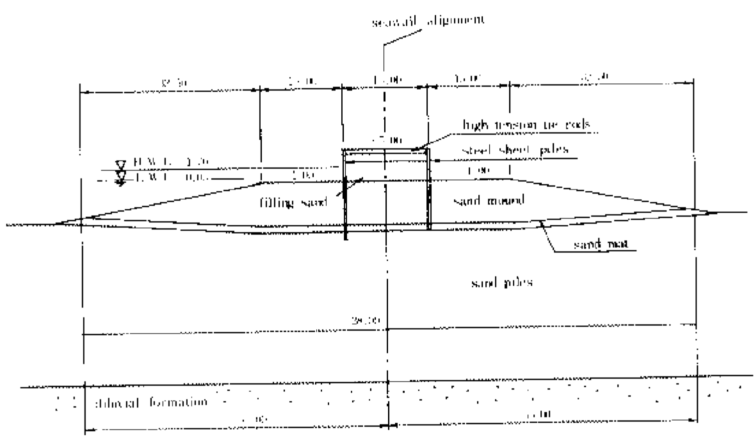

Figure 9. Cross Section of Partition Dike (unit: m)

V) Land Improvement to Alternate Dikes (Figure 10)

Higher seawalls to accept a greater capacity of waste within a limited space lead to substantial increases in construction costs and decreases in the possibilities of land use. Because of the very soft ground conditions, Osaka Port reinforced the settlement by consolidation of a clay layer to increase the capacity instead of making the seawalls higher. The methods of reinforcing the settlement by consolidation are as follows. Sand mat and sand drains are placed on the alluvial formation of the site. When a certain degree of consolidation is achieved by the soil, water contained in the sand mat stratum is pumped out. Thus, reduced water pressure in the drains increases the settlement of the seabed and results in reinforcement of the settlement due to consolidation of more than the above-soil load. With these methods there is an expected increase in the capacity of 4 million m^3 in the North District and 7.3 million m^3 in the South District.

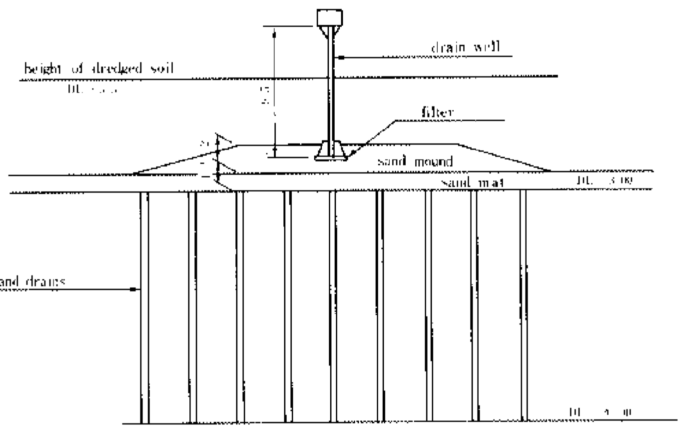

Figure 10. Cross Section of Dewatering with Sand Drains (unit: m)

Measures to Prevent Secondary Pollution

Secondary pollution including waste scattering, generation of foul odors, gases, mice and flies, and exudation of contaminated water must be prevented by the following methods:

- Water quality improvement of the first subdivision by aeration treatment in oxidation lagoons.
- Installation of gas removal facilities to discharge gases generated from waste in the first subdivision.
- Installation of a fence surrounding the first subdivision to prevent waste from scattering.
- In order to prevent scattered waste, foul odors, mice, and flies, 50 cm of soil is placed on every 3 meters of waste when it is treated above the sea level.

Other than the preventive measures above, assessments of water and seabed sediment quality have been conducted inside and outside the site.

CHARACTERISTICS OF THE LAND FILLED BY ORDINARY WASTE

Generation of gas

The first subdivision of the North Port North District is reclaimed primarily by ordinary waste. This subdivision, completed in 1987, is still generating gases by decomposition of refuse among the ordinary waste. In order to discharge gases into the air as soon as possible, 104 gas removal facilities were installed at the beginning of the reclamation. Gases were detected at 63 of the existing 85 facilities as of October 1990.

Composition of the gases generated differs from place to place at the site. Present gases are methane 0-15%, carbonic acid gas 1-20%, nitrogen 36-83%, and oxygen 1-20%. These gases are not toxic, but are referred to as anoxia gases, which contain a low level of oxygen. Also, there is a very low density of hydrogen sulfide among the gases generated, which emits a foul odor similiar to rotten eggs. With regard to the methane present, special attention is given to land use, since explosion might occur by ignition if its density reaches 5-15%.

The amount of methane generated from the existing removal facilities is 13,000 m^3/day, with a variance of 0-75 m^3/h. The annual level of methane generated after completion of the disposal is shown in Figure 11. It has already passed its peak and will continue to slow down slightly but will not drastically decline. Approximately 10,000 m^3/day will continue to be discharged.

Accordingly, it is impossible to seal the gases into the ground completely. For future land use, gases will be collected underground via existing gas removal facilities and discharged through high ducts so that the gas will not affect the land use. Since the source of gases is refuse, the amount of emission is difficult to estimate, therefore monitoring will continue and operational efforts with regard to fire usage is inevitable.

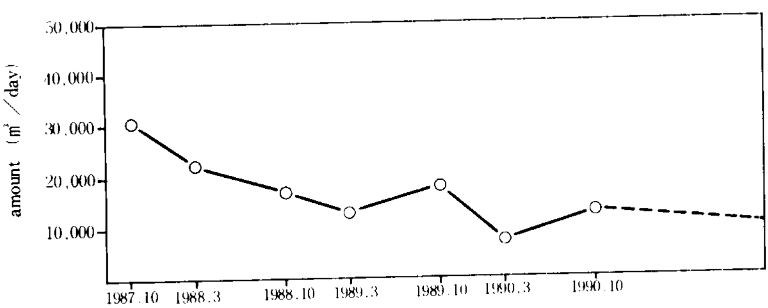

Figure 11. Methane Generated in Subdivision 1 of North District

Land subsidence

"Refuse" disposed land has a high ratio of vacancy and is inherently unstable, so it is prone to settle substantially, unlike land reclaimed by ordinary soil and sand, both during and after reclamation.

The waste disposed stratum in the first subdivision of the North Port North District is 26-30 meters thick. It is composed of glass and stone, metal, paper, wood and plants, textiles, plastic, and refuse from households, etc. (Figure 12). Among the materials, refuse from households occupy approximately 44%, glass and stone about 25%, unidentified substances 10%, and wood and plants 6% of the entire waste of the stratum.

Land subsidence since completion in 1987 is about 5 meters on the average, as shown in Figure 13. The original ground beneath the refuse stratum has subsided by 2.5 meters and the refuse stratum itself 2.5 meters. Potential subsidence of the original ground can be estimated at about 1.5 meters with soil mechanical methods. Refuse is very hard to estimate because of difficulties in analyzing decomposition of refuse by microorganisms.

The duration of decomposition of waste differs by reclamation and maintenance methods. In the case of existing reclaimed land, decomposition is estimated at about 20 years for refuse from households, about 50-100 years for textiles, and about 200 years for wood. Consquently, during the 20 years following completion of the waste disposal site, decomposition is thought to be almost finished, and so the site will be tentatively utilized. The progress of land subsidence and gases generated will be monitored as well. After the condition of decomposing substances is checked, a final land use plan will be established.

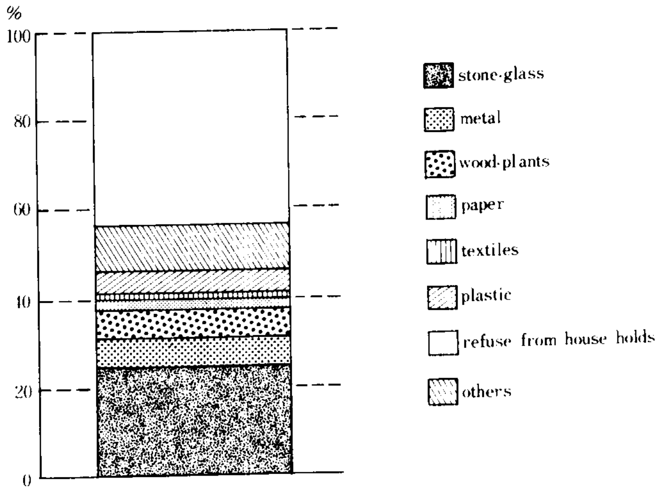

Figure 12. Formation of Ordinary Waste Disposed

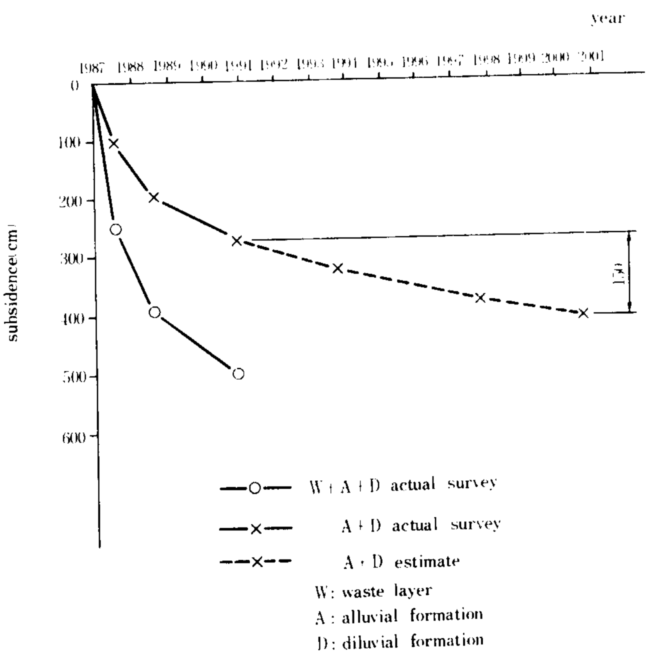

Figure 13. Subsidence Curve

LAND USE

Technoport Osaka Project

At the port of Osaka, a new international business center is planned, which aspires to develop into an international city of information in the 21st century. Reclaimed land with a total area of 775 ha in the North and South Ports will be utilized, along with the redevelopment of the conventional port area. The reclaimed North and South Districts development is based on a long-term plan:

- Upgrading of the port of Osaka as the basis for energetic development of Osaka's economy.
- Upgrading of the port of Osaka as the center of international exchange in Osaka.
- Upgrading the port of Osaka as a space for comfortable living.

With these three basic goals in mind, the Technoport Osaka Project has been carried out at the port of Osaka.

The Technoport Osaka Project, which is set to be developed at three sites within the South Port and the North Port North and South Districts, aims at concentrating three key functions: international exchange, information and communication, and development of state-of-the-art technology. Along with these basic functions, cultural, recreational, and residential facilities will be built. It will be a new city with an around-the-clock exchange of people, goods, and information on an international scale (Figure 14). It is expected that after the completion of these projects (scheduled for the year 2010), Technoport Osaka will have a resident population of 60,000, a working population of 92,000, and a daytime population of 200,000.

Figure 14. Future Plan of Technoport Osaka

In the South Port, the Technoport Osaka Project has already been initiated with the opening of the International Exhibition Center, Osaka (INTEX OSAKA, total exhibition area: approx. 45,000m^2). Future development includes the Osaka World Trade Center (WTC), which will be a center for international trade activity, with a large-scale innovatively designed building of 55 stories above ground (252m in height and approx. 150,000m^2 floor area), and the Asia Pacific Trade Center (ATC), a permanent import and wholesale center (350,000m^2 floor area). Both are under construction now.

As for gathering information and communication, Osaka Teleport, a facility on which 11 antennae for satellite communications can be set up, is complete. For the development of state-of-the-art technology, the Osaka Microelectronics Cooperative as well as computer companies, a training center for tool robot makers, and a calculation center have opened facilities. In addition, a popular town is going to be created by gathering the head offices of fashion clothing and sports goods manufacturers.

In the North Port, at the North District, the waste disposal has been completed and ground improvement works are under construction. At the South District, the waste disposal is under construction.

At the North District, where the sports and recreation zone and the training zone for the international training authority will be situated, the Sports Island Plan is underway.

As for the South District, utilization of reclaimed land will commence from the beginning of the 21st century. It will include deeper draft container terminals as well as business and commercial facilities for international trade. In addition, this district will be a residential zone with upgraded amenities for approximately 60,000 people.

Sports Island Plan (Figure 15)

In response to the citizens' increasing and varying interests in health and sports recreation, various kinds of sports facilities will be constructed in an area of approximately 130 ha, including the first subdivision reclaimed with general waste matters in the North Port District. Main considerations with regard to the Sports Island Plan:

- The citizens' demand for sports and recreation activities.
- The land condition and geographical situation.
- The efficient management of Sports Island.

Due to the improving lifestyles and an increasing amount of spare time, the citizens' interest in sports and recreation has diversified from "competitive sports" to the areas of health, enjoyment, and human relations. To meet these demands, the following four functions were introduced:

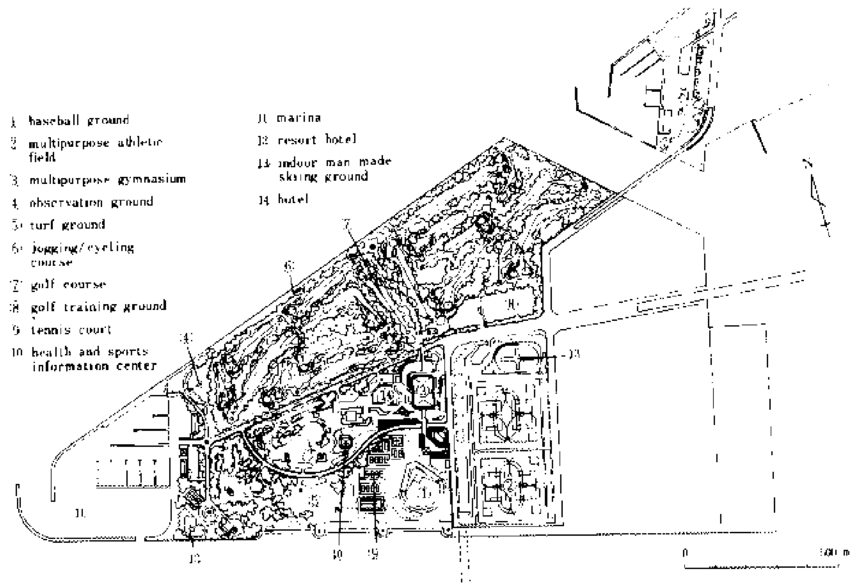

Figure 15. Land Use Plan of Sports Island

(1) Sports. We will build high quality, attractive facilities which compliment the environment as a place where citizens can enjoy various sports and be able to participate in a variety of activities.

(2) Recreation. An urban resort which offers citizens amenities and types of recreation usually unavailable to urban dwellers.

(3) Health. A place for enjoying sports and recreation, while promoting and maintaining health as well as providing health related information.

(4) Education. A place where people can meet and enjoy recreation together. Also, a place to learn about sports, recreation, and health.

In addition to these functions, there will be other facilities to create a resort environment in this area.

Sports Island is located near the city center, with a view of beautiful sunsets. Part of the area was reclaimed with general waste, so that hills and massive buildings cannot be built for about 15 years. In accordance with these land conditions, Sports Island was divided into the following four zones (Figure 16):

(I) Waterfront Zone. Using existing waterfront characteristics such as the sea and the beautiful view, the proportion of water and green areas will be enlarged to create a resort atmosphere in an urban environment.

(II) Hilly Zone. The hilly zone will be a place for outdoor sports as well as an observation plaza and a restaurant with a view. The hills along the water's edge will become part of the "green belt" in the port of Osaka.

(III) Facility zone. Large-scale athletic facilities utilizing vast flat areas will be made available to citizens for multi-purpose use, and athletic and outdoor activities for school children. The training and recreation facilities for young and aged will be built facing the forest and pond, with a beautiful landscape.

(IV) Center Zone. The center of North Port North District will connect each zone at the center area of Sports Island. At this central point, there will be a common area where people can gather.

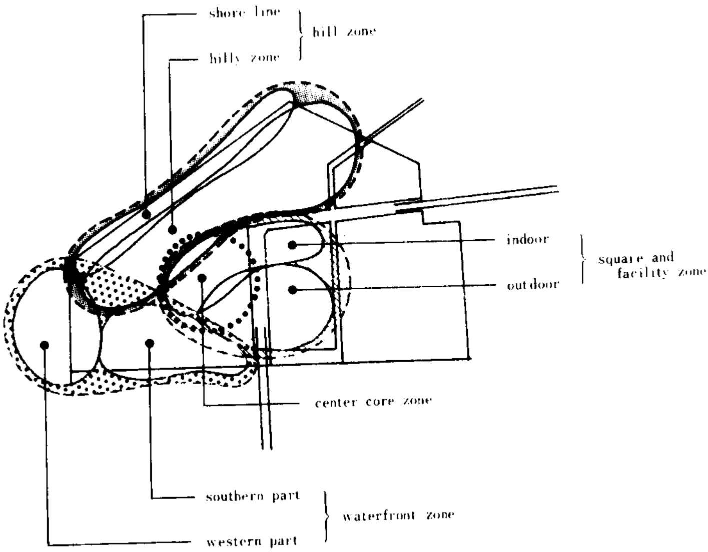

Figure 16. Zoning Plan of Sports Island

As for the implementation of this plan, we basically consider the following four aspects:

• This project aims to develop the vast area deployed at the waterfront and to organize the development of the whole area. The task of land use designation and administrative functions will be handled by the City of Osaka or a public organization to oversee a unified system.

• To insure an adequate budget from the early stages, an efficient performance and operation level needs to be maintained by introducing the knowledge, funds, and talented staff of private organizations.

• A proper organization will be chosen as a business proprietor for the various facilities according to its needs.

• The costs of maintaining and renewing green areas will be met by the users and developers.

This project will be carried out by three types of organizations: a public organization with the City of Osaka as the center, a private organization with private enterprises as the center, and a public/private (third-sector) organization as business proprietor for each facility. We will proceed with each project organization as follows:

(I) Public Initiative Project. A public proprietor will develop the standard facilities as urban facilities in each zone, including both free-to-the-public and private facilities. The City of Osaka will be in charge of the construction, and a third-sector organization will be in charge of overall management and operation of the facilities. Also, transportation access will be upgraded for convenient use of Sports Island and expansion of facility use.

• Baseball ground, multi-purpose athletic field, multipurpose gym, outdoor activity facilities, training facilities, observation plaza, forest zone, seaside promenade, events square, lawn plaza, and rest house.

(II) Public/Private (Third Sector) Initiative Project. This sector will combine profitable facilities with facilities expected to offer high-quality service. Although these projects are by independent budget, they will be developed from the public viewpoint and handled as public facilities.

• Golf course, golf-practice center, tennis court, view-restaurant, health and sports information center, marina resort hotels.

(III) Private Initiative Project. The following projects are profitable and at the same time dependent on a large amount of investment, to be undertaken by an enterprise with suitable experience and capital.

• Indoor skiing slope, hotels, training facilities, recreation facilities for young and aged, long-stay facilities, education and study facilities.

Total cost of this project (cost of land excluded) is estimated at approximately ¥121 billion, of which approximately ¥18 billion to public business proprietors, approximately ¥40 billion to third sector proprietors, and approximately ¥63 billion to mainly private proprietors. The completion of Sports Island is scheduled for 1997.

CONCLUSION

In October 1990, Osaka City announced a "New Master Plan," which will guide the formation of the city in the 21st century. The basic principle of this plan is to create a city for people and to create a city for international benefit, which is totally balanced for "accommodation," "working," and "recreation." In this new plan, the Technoport Osaka area and the conventional waterfront area are supposed to become a new city center, with the advantageous location (located in the middle of the Osaka Bay area development project) and abundant possibilities for development. We plan to integrate the latest urban functions in this area, so that it will lead the city's development and become a new city center, and make a double city centers structure. To continue the development of Osaka's waterfront, a plan for another reclaimed island has commenced.

To keep in step with changes in the international business structure — enlargement of vessels, and increase of aircargo volume and passenger transportation — a new island is urgently needed. The new island will also be used for the construction of deep draft container terminals and it will enable us to rearrange the safe harbor passage system.

To create a safe and comfortable urban life in the City of Osaka, we urgently need to enforce the new island plan to secure final waste disposal with a long-term view, as well as to restrict the total amount of waste and to build recycling systems for waste.

The City of Osaka, which has limited space, needs to construct a new man-made island where the waste is effectively used as the material for the reclamation. We can create a safe and comfortable port area, where city and port functions are beautifully organized.

(Edited by P.M. Grifman)

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Comprehensive Development of Tidal Flats in Zhejiang, China

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ABSTRACT

As one of the ten maritime provinces in China, Zhejiang has many tidal flats along its zigzag coasts of continent and islands. In accordance with the local economic situation and the properties of tidal flats, comprehensive utilization of the tidal flats is developed, which can be seen as the combination of agriculture, forest, livestock raising, fishery and fruit planting etc. Therefore, the water, land and space of the tidal flats are all used in a complex system of development.

This comprehensive development model of tidal flats also builds a good and effective ecosystem, from which the local people benefit a great deal. This model has been regarded as an effective developing model of tidal flats in China, and it may be also helpful to others, especially to the developing countries.

INTRODUCTION

Situated at the central part of the West Pacific Rim and China's coastline, Zhejiang is regarded as a province of great significance in the open policy of the coastal areas of the country. As one of the ten maritime provinces in China, Zhejiang plays an important role in economic reform and international trade of the country.

In Zhejiang, there is coastline of about 6140 kilometers, which includes 1840 kilometers of continental coastline and 4301 kilometers of islands coastline. There are 1921 islands in Zhejiang, which ranks the province first in numbers of islands

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among the ten coastal provinces of the country. It has a total area of 8821 square kilometers, and many tidal flats along the zigzag coasts of continent and islands.

We define the tidal flat as a special zone located between the lowest level and highest level of the spring tide. Theoretically, the tidal flat is from the coastline to the theoretical datum line of the sea level.

With a population of 41.4 million in 1990, Zhejiang is more densely populated than other provinces and land reclamatiom is very important. The tidal flat is certainly one of most important land resources in Zhejiang. Besides the land resource, there are also various kinds of other resources on the tidal flats, such as fishery, salt, minerals and forage grass etc., so the local government has paid much attention to comprehensive development of the tidal flats.

TIDAL FLATS IN ZHEJIANG

Some characteristics of the tidal flats in Zhejiang can be described as follows:

(1) There are more than 1000 kilometers of coastline consisting of muddy and silt coasts and about 800 kilometers of the coastline is rocky coast in Zhejiang. Of the total area of 2886 square kilometers of tidal flats of the province, most of them are composed of mud and clay (2817 sq. km). Most of the tidal flats are along the continental coast (2566 sq. km) and only 320 square kilometers are around the islands.

(2) Sediments of the tidal flats are derived mainly from the continental shelf of the East China Sea and a part from riverine flows. Most sediments are accumulated on the tidal flats by wave movement and tidal currents.

(3) Tidal flats can be divided into three patterns according to their geographic distribution. Most are located out of the alluvial plain of river mouths, and the width of these tidal flats can reach 5-6 kilometers, such as the tidal flats in Qiantangjiang Estuary and Oujiang Estuary, which comprise 1888 square kilometers; part are in semi-closed bays such as Shanmen Bay and Legin Bay, areas of 819 square kilometers; and only a small part of the tidal flats are along the coast of islands.

(4) Tidal flats can be also classified into three types by the degree of stability — accumulating, stable and erosive. Most tidal flats belong to the accumulating and stable types, and are suitable for multi-purpose development.

(5) All the tidal flats in Zhejiang are controlled by the subtropical monsoon climate. Moderate temperature and plentiful rainfall make the tidal flats suitable for agriculture and fish breeding.

(6) The alternation and seasonal changes of riverine flow and cold and warm oceanic currents provide good living conditions for fish and other kinds of sea animals.

(7) Herbs are the dominant vegetation on the tidal flats. Two common kinds of vegetation are *Scripus marigueter* and *Spartina angelica*. Others include *Suaeda salsa*, *Phragmites australis* and *Aeluropus littoralis var. Sinensis*. There are 586 species of

animals and 169 species of algae on the tidal flats. *Tegillarca granosa (Linnaeus)* and *Littorina brevicula (Philippi)* are the most frequent species.

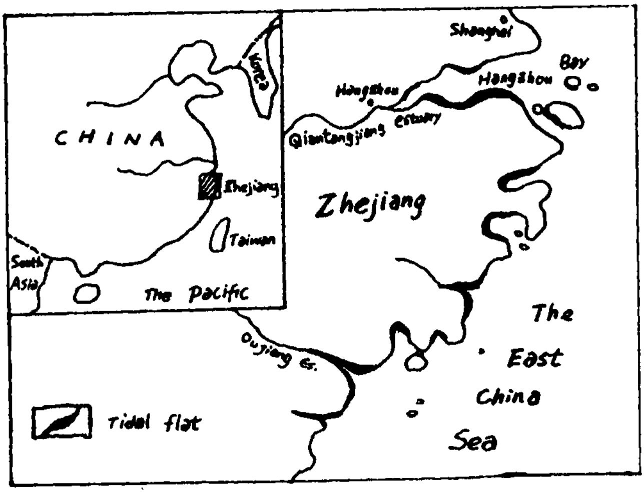

Figure 1. Map showing the location of Zhejiang and its tidal flats

COMPREHENSIVE DEVELOPMENT OF TIDAL FLATS

A long history

It has taken thousands of years to reclaim the resources of tidal flats in Zhejiang. Archaeologists have found many relics such as ancient rice, fish bones, fossils of animals, shells and cottages etc. on the southern bank of Hangzhou Bay, where a river mouth is located. Using the C-14 dating method, we can deduce that all the relics were from 6000-7000 yrs. BP, the Neolithic Epoch.

In accordance with historic records, we found that the earliest seawall on the northern bank of Qiantangjiang Estuary was built in the Eastern Han Dynasty (25-220 AD). From then on, there were more and more development activities on the tidal flats; for example, salt production was a use of coastal water and tidal flats. Early in the Western Han Dynasty (206 BC-24 AD), many salt sites had been built on the tidal flats.

Multiple uses

Multiple uses are in various fields, including agricultural reclamation, fishfarming, salt sites, recreation, ports and harbours, etc.

Development value

There are many physical factors influencing the comprehensive development of tidal flats. These factors are as follows:

- Climatic factors: temperature, rainfall, evaporation, direction and strength of wind,and typhoon processes;
- Oceanographic factors: tidal range and current, sediment concentration, water temperature, wave conditions, and nearshore sediment current;
- Seawater chemistry: nutritional elements, and soluble oxides;
- Biological factors: plankton, benthos and swimming animals;
- Physical properties of tidal flats: area, altitude, location, topography, sediment and slope changes;
- Others, such as the property of freshwater derived from the drainage basin.

Based on the relationships among the factors mentioned above and the different kinds of development purposes, we can regard some conditions as suitable for the comprehensive development of tidal flats. For example, to develop the tidal flats for fish farms or fish breeding, moderate waves, slower current speeds, plentiful plankton and a wide tidal face will be regarded as favorable conditions. To use the tidal flats for agricultural reclamation requires a wide tidal flat, good sediment conditions, and a stable or accumulating coastline. To make use of tidal flats for salt sites, we generally consider seawater salinity, the annual temperature, evaporation and the sediment properties of tidal flats. A beautiful sand beach and wonderful rocky coasts will be suitable for developing into recreational sites. Other special tidal flats for this kind of use include some salt marsh, river mouth, barriers and islands. Qiantangjiang Estuary, for example, is famous for its tidal bore. To build ports and harbours, deep water and a stable coastline are necessary.

Products of the comprehensive development of tidal flats

Because of the great significance of the comprehensive development of tidal flats, especially the value to the national economy, people have recently given more consideration to the development of tidal flats. The main products of comprehensive development of tidal flats in Zhejiang by the end of the 1980s are shown in Table 1.

Table 1
Main Products of Comprehensive Development of Tidal Flats

Development type	Total Area (sq. km)	Main Products	Area (sq. km)	Production (tons)
agricultural land	601	rice	225	148175
		cotton	214	21090
		vegetable oil	105	15850
		sugarcane	15	127680
		silk	8	715
		others	>34*	>23000*
fish farms	122	fish	58	4103
		shrimp	65	5796
garden		fruits	101	116510
salt sites	118	salt	118	312270
recreation	5*	—	5*	—
others	>117	—	>117	—

*estimated data

CASE STUDY: A COMPREHENSIVE DEVELOPMENT MODEL OF A TIDAL FLAT

A real example of comprehensive development of a tidal flat is shown in this example, which is regarded as a very effective model for multiple uses of tidal flats in Zhejiang and China.

General information

About five years ago, this tidal flat was reclaimed. Its total area is 1.35 square kilometers, 76% of which had been used. Sediments of the tidal flat are mainly silt and mud. It lies in the subtropical monsoon climatic zone, with plentiful rainfall and sunshine. Three years ago, a primary farm was set up.

Management

As a comprehensive development system of fishery, agriculture, livestock and forest, the farm also integrated the technique with developing production and trade. Therefore, management includes three aspects:

a. Technical management: to sign and develop technical agreements, to carry out the concerned policies, to pay more attention to technical achievements and transfer them into productivity, and to set up a technical archive;

b. Production management: each farmer should be responsible for his or her work, or must suffer the consequences. Extra work warranted extra reward;

c. Trade management: to build a service system for promoting the trade of farm products within or out of the province or to other countries.

Products

In accordance with the principle of multiple uses of tidal flats, we set up a complex development system in which the water, land and space of the tidal flat are fully used.

Fish breeding is the main project of the farm. The farmers also raise various kinds of livestock and build the forage base. Through the feed-processing plant, forage grass and forage crops become a fine forage for livestock and fish. Sediment from the the bottom of the fish pools and the muck of livestock can be used for manuring the pasture grass, forest and other agricultural fields.

As mentioned above, the farm is a combination of fishery, agriculture, livestock and forest. The main products of each are as follows:

- In the fishery, shrimp, eels, pearl shells and crabs are the main products on the farm;
- Products in agriculture include rice, various kinds of vegetables, fruits such as grapes, peaches and watermelon;
- Livestock includes pigs, ducks, sheep, hens and cocks;
- Forest is used to protect the coast from erosion and to produce timber.

By the end of the 1990s, there are more than ten kinds of products from the farm, both for domestic markets and for export to other countries. In the past three years, nearly 18 tons of eels of which 12 tons were exported, 275 tons of fish, 657 tons of watermelon, 40 tons of vegetable, 1.2 tons of pasture seeds, 55 tons of rice, 35 tons of vegetable oils and many pigs, sheep, hens and cocks were produced on the farm. Both the farmers and the investor benefit a great deal from tidal flat reclamation.

As a comprehensive development model of the tidal flat in a developing country like China, this model should be instructive to colleagues from other countries. We also hope through this brief introduction to promote cooperation among ourselves.

CONCLUSIONS

Situated at the central part of China's coastline and Western Pacific Rim, Zhejiang is one of the important maritime provinces and it is of a great significance to develop the tidal flats. Multiple uses of tidal flats in Zhejiang include:

Agricultural land reclamation — including plant crops, livestock, fruits, and forest; fishery — including fish, shrimp, eels, and pearl shells; salt — to reclaim the tidal flats into salt sites for producing salt; marine transportation — to build ports and harbours on deep water coast (generally in low tidal flats and rocky coast); recreation — sand beaches, salt marshes and other charming scenic spots on the tidal flats.

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Coastal Zone Technologies and Energy

27

Improving Coastal Zone Decisions by Use of Science and Technology

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One of the highly used and most complex areas of the United States and the world is the coastal zone — from the inland tidal areas to well offshore of our coasts. Similar areas include the Great Lakes, other large lakes and the shores of large reservoirs. The zones are of primary interest from an environmental perspective, for recreation, for industry, for transportation, for coastal related agriculture and other major factors. Unfortunately our greatest unsolved problems, concerns and conflicts relate to this zone, and furthermore we are unable to understand and quantify the complex physical forces and processes of the coastline. There is an urgent need for a firm theoretical and practical understanding of interrelation of the complex and varied environmental factors that interact at the coast. One of the major elements of these interactions is the qualification and understanding of hydrodynamic and physical components of the coastal waves, currents and coastlines with coastal sediments and structures.

Due to the major financial commitment required to solve coastal related problems, America is slipping behind in its capability of responding adequately to these problems. We have observed that many foreign governments, faced with similar financial restrictions, are assembling national facilities which meet the needs of universities, the private sector, and public bodies to study and solve urgent coastal problems. The Netherlands at the Delft; The United Kingdom in Wallingford, England; The Canadian National Research Council in Ottawa, Canada; and many others have formed effective major national facilities. Fortunately, the United States can already claim such major facilities as the Waterways Experiment Station/Coastal Engineering Research Center in Vicksburg,

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Mississippi, as well as facilities at universities and in the private sector which all represent excellent bases for development.

However, as good as the United States and foreign facilities are, and as well intentioned were the plans that tried to delve into one of the world's most complex problems — the inner space of the coast where land, sea, and air meet, it is our belief that our existing facilities at the present time are inadequate to prove theoretical relations and more importantly, find factual answers to our coastal problems and concerns.

We believe that there are at least three major areas of concern for which all facilities, including those in the United States are sadly lacking:

1. The quantification of the movement of sands and coastal sediments in our coastal, lake, and large reservoir areas, as well as our barrier islands and coastal inlets.
2. The stability of large coastal structures.
3. The impact of sea (or lake) level change on beaches and shores.

The complexity and cost of a facility to meet these areas of concern is not economically feasible for single private firms or groups of firms in the United States and not politically practicable for individual states or other political jurisdictions. Realizing this, we believe that consideration should be given to developing a National Coastal Facility, possibly in coordination with other nations, operating on a sound technical basis and under a capable management structure responsive to public needs. The direct operational costs would be rendered by the individual users within the constraints and support of the Federal Government.

In order to assess the theoretical, scientific and technical feasibility of a National Coastal Facility, a two day meeting was held at the Beckman Center of the National Science Foundation in southern California under the auspices of the American Society of Civil Engineers, the Coastal Zone Foundation and the American Shore & Beach Preservation Association. The attendees at this meeting were:

Dr. Robert G. Dean, Professor, University of Florida, Gainesville, FL

Mr. P.F. Dunn, Chief, Planning Division, Corps of Engineers, San Francisco, CA

Dr. Billy L. Edge, Edge & Associates, Charleston, SC

Dr. Jim Houston, Director, Coastal Engineering Research Center, Vicksburg, MS

Dr. Bernard LeMehaute, University of Miami, Miami, FL

Mr. Orville Magoon, President, Coastal Zone Foundation, and President, American Shore & Beach Preservation Association, Middletown, CA

Mr. Thorndike Saville, Consultant, Bethesda, MD

Dr. Richard Seymour, Scripps Institution of Oceanography, La Jolla, CA

Dr. Rod Sobey, University of California, Berkeley, CA

Dr. L. Vincent, Coastal Engineering Research Center, Vicksburg , MS

Dr. Robert Whalin, Technical Director, Waterways Experiment Station, Vicksburg, MS

Professor Robert L. Wiegel, Chairman, Coastal Engineering Research Council, University of California, Berkeley, CA

The meeting attendees concluded that it would be technically feasible to construct a National Coastal Facility, that such a facility would be able to vastly advance the science of coastal processes, improve the state-of-the-art of coastal hydrodynamics and provide vastly improved solutions and answers to technical problems of coastal areas. The facility would allow the United States to lead other nations in coastal engineering and coastal science and improve the competitive advantage of American firms involved with coastal studies, coastal engineering, coastal planning and coastal construction. This facility would also provide better information for government decision makers to improve coastal zone decisions.

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The Potential of Ocean Energy Conversion Systems for Island and Coastal Applications

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ABSTRACT

The oceans occupy almost three-quarters of the earth's surface and represent an enormous source of non-polluting, inexhaustible energy. They are a renewable energy resource that could offset reliance on combustion of fossil fuels, help resolve the related environmental problems of global warming and air pollution, and with some systems, offer co-products that could improve the economic feasibility of these energy technologies, particularly for island and coastal regions.

While many of the major developed nations have conducted exploratory research and development, and even installed a few commercial facilities, the total operational power available is far less than 100 megawatts. However, projected available ocean power far exceeds the energy consumption of mankind, making this option extremely attractive, especially when the full economic and environmental implications are considered. Much of the development — tidal, wave, salinity gradient, current, and wind energy — thus far has focused on energy production. Of these, relatively little progress has been made with salinity gradients and currents. Tidal, wave, and wind power have strong potential for further refinement and are within an acceptable range for economic competitiveness. Two other options, ocean thermal energy conversion and marine biomass, promise multiple products. In fact, the real attraction of ocean energy is the combination of largely benign (and perhaps even enhanced) effects on the environment and the guarantee that the resource base will be available as long as the sun shines.

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INTRODUCTION

Since the dawn of the industrial age, the demand for energy has been increasing rapidly, and is accelerating to keep up with exponential population and economic growth. The combustion of fossil fuels has been meeting the major portion of the needs, followed by nuclear power. However, there is a growing concern about the relationship between fossil fuel combustion and global warming and air pollution, extraction of oil and gas, oil spills, and dwindling supplies of oil and gas which may be exhausted by the middle of the next century.

Totally safe nuclear power would be an alternative, but society has not been receptive because of potential catastrophic failures and problems of radioactive waste disposal. Therefore, alternative energy sources that are nonpolluting, economically competitive, and relatively inexhaustible are needed to meet the burgeoning needs of society.

Solar energy is an inexhaustible, nonpolluting source that has great potential as an alternate energy source for the future. It can be processed directly through thermal and photovoltaic methods currently being applied to solar-heated and powered homes. Solar energy can also be processed indirectly by converting the dynamic motion of wind, waves, and currents induced by solar winds; converting ocean thermal and salinity gradients; and converting biomass energy derived through photosynthesis.

This paper provides an overview of development and use of ocean energy conversion systems and their application to islands and coastal regions. The development efforts include ocean thermal, tidal, wave, current, and salinity gradients. Extracting wind energy in the coastal environment also has good potential. Ocean and wind energy systems may be distant from the consumer and may often rely on resources that vary in magnitude as a function of time on a diurnal and seasonal basis. These problems can be reduced by using some or all of the energy for generating fuels such as hydrogen that can be stored and used on demand. Each of these ocean energy systems is briefly covered herein regarding techniques used; international development status; and an assessment of technical, economic, and environmental issues and research needs. An intercomparison of the systems is made and conclusions presented.

BACKGROUND

World population has been growing exponentially over the last 40 years and is expected to nearly double over the next 40 years, from over 5 billion to about 9 billion. This steady increase equates to less land per person; a greater need for food, energy, and material resources; and a significant impact on our environment. While the population may be doubling in 40 years, the rate of energy consumption is doubling at a present rate of every 12 years. The world's energy demand is currently being satisfied by various forms of fossil fuel and nuclear power; however, the detrimental effects of our overwhelming reliance on fossil fuels are becoming more and more obvious.

Power plants and vehicles release gaseous emissions that are transported by clouds and winds aloft and eventually settle down as acid rain that kills aquatic life in streams, lakes, and estuaries; pollutes water supplies; destroys terrestrial foliage; acidifies soils; and damages buildings and materials.

The phenomenon of global warming, meanwhile, has been attributed to atmospheric accumulation of greenhouse gases, such as carbon dioxide and methane, which act like a blanket to trap the sun's radiant heat. Greenhouse gases are produced by all forms of combustion, especially by automobiles and power generation. The environment's ability to assimilate carbon dioxide is being reduced because expanding urban development, deforestation, and destruction of rain forests increase the losses of trees and vegetation — the natural assimilators of carbon dioxide. The processes and capacity of our oceans to assimilate or release carbon dioxide is not well known at this time. Though exact figures cannot be predicted, the general consensus is that global warming will increase and produce deleterious effects impacting agriculture, causing sea-level rise, and affecting the quality of life. Sea-level rise could flood island and coastal cities and villages and create a concern in designing and constructing homes, buildings, ports, and harbors for future coastal communities.[17]

In addition, past oil crises have created sudden, sobering evidence of the magnitude of our oil dependence. While this prompted some efforts for conservation and for alternative energy, low oil prices in the 1980s dampened these efforts and consumption of oil increased to even greater levels. More recently, the present instability in the Middle East once again brought attention to our great dependence on oil and further emphasized the need for alternative energy sources. A global accounting of the amount of discovered and yet-to-be-discovered fossil fuels, when compared with a projection of energy consumption, results in the realization that we will consume the readily-accessible portions of this resource within a relatively short time. Oil and natural gas will be essentially depleted by about 2030 and coal will last into the 22nd century. These periods are very short from a historical perspective and should be within the planning horizon of nations, states, and other communities.

Solar energy has gained perhaps the greatest recent attention, and many approaches to harness the sun's power are now being explored. The major drawbacks to direct usage are intermittent availability and variation in energy intensity. Large storage facilities are necessary for uninterrupted and steady use of solar power. Luckily, a naturally occurring large-scale facility already exists — the tropical oceans.

ENERGY SYSTEMS IN THE MARINE ENVIRONMENT

The oceans are the world's largest solar energy collector and storage system. On an average day, 60 million km of tropical seas absorb an amount of solar radiation equivalent in heat content to about 245 billion barrels of oil. If less than 0.1 percent of this stored solar energy could be converted into electric power, it could supply the equivalent of more than 20 times the current total U.S. electricity demand[12] or about five times current world consumption.

This incident solar energy is stored in the ocean, either directly in the form of thermal heat or indirectly as wind, waves, and currents created by the temperature differences between the tropical and arctic waters. The availability and potential of these energy forms have led to the development of ocean energy systems to harness solar energy. The availability of much of this energy is very site-specific and the conversion efficiencies very low. While many of these systems have experienced only minor commercial use, the potential for a significant contribution to the world energy economy does exist and there is a continuing interest in the research and development of these relatively clean, safe, renewable energy systems. Presently, the more highly-developed ocean energy systems are ocean thermal energy conversion and tidal, wave, and wind energy. The less-developed ocean energy technologies are ocean current turbines, salinity gradient devices, and biomass conversion.

Ocean Thermal Energy Conversion (OTEC)

The concept of ocean thermal energy conversion is to extract energy from the temperature difference between surface and subsurface ocean waters. Solar energy has been absorbed and stored as heat in the upper layer of the ocean; cooler water transported from the polar regions lies below. The cost of energy recovery drops as the temperature differential increases. The temperature difference between the surface layer and water 1,000 meters deep is at least 20 C in tropical and subtropical areas all year. OTEC plant concepts range from shore-mounted plants with ocean intake pipes to fixed and moored offshore plants to drifting plantships.

OTEC techniques are based on either the closed- or open-cycle concept, with hybrid combinations also gaining in interest.[14] In the closed-cycle plant, warm surface water is used to evaporate an enclosed auxiliary working fluid such as ammonia or Freon. The vaporized working fluid drives a turbine which, in turn, drives an electrical generator. Cold water from a depth of 1,000 meters is used to condense the vapor after it has passed through the turbine, much like in a steam power plant. The working fluid returns to the evaporator to be recycled. The open-cycle system, attempted by Claude in Cuba in 1930, uses the warm sea water as the working fluid. The pressure above the warm water is lowered sufficiently for the water to boil and vaporize. This vapor is used to drive the turbine and cold, deep water is required to condense the water vapor exiting from the turbine.

Table 1 lists most of the main OTEC development projects over the past decade, ranging from proposed to constructed, tested, and evaluated. Until economic feasibility is demonstrated, none have been developed for commercial operations.

Table 1

OTEC Development Projects

Country	Location	Year	Size (kW)	Type Cycle	Comments
USA	Hawaii	1979	50	Closed	Mini-OTEC (Built & Tested)
USA	Hawaii	1981	1,000	Closed	OTEC-1 (Thermal Exch Test Only)
USA	Hawaii	1984	40,000	Closed	Proposed (Inactive)
USA/UK/CAN	Hawaii	1991	180	Closed	Planned
USA	Hawaii	1993	165	Open	Experimental (DOE)
Japan	Nauru	1981	100	Closed	Built & Tested
Japan	Kyushu	1982	25	Closed	Built & Tested
Japan	Tokunoshima	1982	50	Closed	Built & Tested
Japan	Univ of Saga	1985	75	Closed	Thermal Exch Test Only
Taiwan	East Coast	1991	5,000	Closed	Proposed (Inactive)
France	Tahiti	1985	5,000	Closed/Open	Proposed (Inactive)
France	Africa	1985	3,000	Closed	Proposed (Inactive)
UK	Caribbean	1982	10,000	Closed	Proposed (Inactive)
UK	Hawaii	1989	500	Closed	Proposed (Inactive)
Sweden	Jamaica	1983	1,000	Closed	Proposed (Inactive)
Netherlands	Bali	1982	250	Closed	Started (Inactive)

While the French were the first to suggest and construct energy conversion systems for extracting stored solar energy from the sea, the 1979 Mini-OTEC project conducted in Hawaii was the first to demonstrate net positive electricity. OTEC development has since been primarily sponsored by the Department of Energy, with limited involvement from the private sector. Early interest focused on 50-MW closed-cycle designs. Since then, concentration has been on small, island-based open-cycle plants.[10] Present efforts by the Department of Energy have involved the design and construction of a 165-kW Net Power Producing Experiment open-cycle plant in Hawaii for experimental use in the 1993 time frame to develop models for performance prediction in determining technical and economic feasibility.

Several nations besides the United States are interested in developing full-scale OTEC plants.[12] Japan has completed design studies of a 10-MW floating plant and 3-MW shelf-mounted plant to be located off the coast of Okinawa. Earlier experimental plants were constructed on the Japanese island of Tokunoshima and in the Republic of Nauru. Design studies have been made for other locations in the Pacific, with an emphasis on small, closed-cycle plants. The Taiwan Power Company completed studies on the feasibility of placing 50-MW plants on the eastern coast of that country,[15] projecting that such plants will become competitive with oil- and coal-fired plants in the mid-1990s. The Pacific International Center for High Technology Research completed a strategic plan for Taiwan, proposing a $72-million, 5-megawatt, multi-product, closed-cycle system.

GEC-Marconi and Alcan International of Canada reported preliminary design work on a small, land-based, closed-cycle OTEC plant planned for Keahole Point in Hawaii to provide the technical basis for scaling up to commercial-sized 10-MW plants. The French government, under the leadership of IFREMER, has conducted feasibility studies, beginning in 1978, aimed at constructing an experimental facility on Tahiti. Site evaluation studies and designs for open- and closed-cycle systems were completed but no further work has been conducted since. The Netherlands, in cooperation with several Indonesian companies, completed a feasibility study for a 100-kW closed-cycle plant at a South Pacific site. The governments of Sweden, Norway, and Jamaica have been cooperating with private companies since 1980 in designing a 1-MW closed-cycle plant to be located near Kingston. OTEC progress has ranged from slow to inactive because of the low cost of oil, but recent increases in late 1990 may accelerate interest once again.

The combined production of electricity and fresh water using the principle of OTEC is cost-effective under certain scenarios defined by the fuel cost of electricity production, with conventional fossil fuel plants, and the production cost of water. At least four scenarios can be envisioned (Table 8). To move forward with the development of OTEC, demonstration plants must be built and operated. Demonstration plants should be scaled versions of commercial plants and be operated for at least a couple of years to convince the financial community to invest.[18]

Like any offshore or shoreline project, commercial OTEC facilities will affect the marine environment. Construction activities may temporarily disrupt the sea bed, destroying habitats and decreasing subsurface visibility. Platforms and marine subsystems may attract fish and other marine species, and maintenance routines to reduce biofouling may increase the level of toxic substances. However, OTEC systems can be designed and located to minimize their potential effects on the environment and even enhance the surrounding ocean, as shown by Mini-OTEC, when augmented fish catches were reported near the site off the Big Island of Hawaii. OTEC developers can minimize disruption by locating plants away from critical habitats. Where necessary, cables and pipes can be routed through natural breaks in near-shore reefs. Short-term disruption of habitats is often reversible, as shown by experience with offshore oil rig construction.[12]

OTEC plants discharge large quantities of ocean water and could potentially affect natural thermal and salinity gradients and levels of dissolved gases, nutrients, trace metals, carbonates, and turbidity. If cold- and warm-water streams are mixed and discharged at the surface, the density of OTEC plant discharges will be different from that of the surrounding water. OTEC plants can be designed to stabilize the discharge plume below the mixed layer to protect the thermal resource and to minimize potential environmental effects. However, a key point to consider is that the intelligent management of this discharge could stimulate living marine resources.

An environmental impact of a more serious nature could occur if ammonia, Freon, or some other environmentally-hazardous working fluid was accidentally spilled from a closed-cycle OTEC plant. Small quantities of ammonia probably would stimulate plant growth downstream but a large spill would be toxic; for example, a 40-MW plant could release enough ammonia to destroy marine organisms over an area as large as four square kilometers.[12] This possibility can be minimized by designing the plant for safety and careful operation.

OTEC facilities release no additional heat and significantly less carbon dioxide than comparably-sized conventional fossil-fueled power plants. These advantages may become increasingly important in the future if predictions concerning global climate change are correct and power plants are required to reduce carbon dioxide production significantly.

It has been projected that circulating and warming large amounts of deep ocean water in any OTEC plant operation could result in outgassing of dissolved carbon dioxide if the discharge is exposed to the atmosphere for sufficient periods. Recently-completed experiments indicate that the immediate carbon dioxide release from an open-cycle OTEC plant would be 15-25 times smaller than the emission from a comparably-sized fossil-fueled electric power plant.[9,4] The variability of natural outgassing in tropical oceans will greatly exceed any projected OTEC release. The release of carbon dioxide could be ameliorated if the discharge water is used for mariculture or other secondary operations. Most of the potential long-term and immediate releases can be avoided completely by re-injecting any absorbed gas into the sea water discharge,[9] introducing that discharge below the surface-mixed layer of the ocean, or combining these methods.[14]

There is an increasing awareness that the multi-product potential of OTEC plants to provide power, water, food, and refrigeration to remote island communities in an integrated system will stimulate their economic development. Such a prospect appears attractive even in the near-term.[13]

Energy costs have been predicted for an OTEC plant using an ammonia-based closed-cycle system situated on a fixed platform near Kahe Point, Oahu, Hawaii. This site is particularly well-suited because of the steep slope of the ocean bottom and proximity to an existing 600-MW oil-fired power plant owned by the Hawaiian Electric Company. The OTEC power plant also benefits by using the warm water being discharged from the oil-fired power plant. The unit would have a nominal power output of 40 MW. The temperature of the warm sea water intake of the heat exchangers is increased by approximately 1.6 C using the warmed cooling water leaving the HECO plant. The temperature difference between the warm and cold water at the design point is 21.4 C. The proposed power system has four 10-MW (net) modules housed in a concrete structure built off-site and floated to Kahe Point. Cold water will be supplied through a pipe extending approximately 3.2 kilometers (2 miles) seaward to a depth of about 670 meters (2,000 feet). In 1985, the predicted installed cost was estimated at $558.9 million, giving a unit capital cost of $12,200/kW and the cost of electricity produced at $0.255/kWh. A contingency of

30 percent was included in these estimated costs.[1] In constant 1990 dollars, the capital cost was estimated at $15,500/kW and electricity at $0.324/kWh.

A small amount of natural chlorine can control biofouling on the warm water side, and roll-bonded aluminum has been developed to replace titanium heat exchangers, reducing costs by up to a factor of five. The major components still undergoing development include open-cycle turbines and flexible cold water pipes using bottom-mounted pumps.

For onshore and shallow water near-shore fixed plants, cable transmission of the electricity from the plant does not represent a technological problem. However, for offshore plants moored in deep water, the technology is being developed in the Hawaii deep ocean transmission cable project where sea floor cables at depths of 7,000 feet are being designed to transmit electricity between islands. Production of energy-intensive secondary products, such as hydrogen, ammonia, or methanol, also has been proposed for moored or drifting OTEC plants which would alleviate the need for such cable technology. In the case of a sea-floor-mounted cold water pipe, the structural concerns regarding the cold water pipe system, have been somewhat alleviated by the successful deployment and prolonged use of a cold water subsystem at the Sea Coast Test Facility at Keahole Point, Hawaii. The success of this facility has proven the reliability of present cold water pipe technology for small (under 1 MW) OTEC plants. In the long-term, innovative pipe designs, such as a soft, flexible pipe, will need to be developed for facilities approaching and exceeding 100 MW.

Tidal Energy

Tidal energy is generated by collecting rising tidal water behind a barrier and then releasing it at ebb tide through turbines to generate electricity. Systems are available to extract energy by relatively conventional hydroelectric turbines and related structures. The use of conventional technology separates the development of tidal power from other ocean energy sources. Low-head, axial-flow turbines are the modern means of harnessing the relatively small differences in water level in a river system or from a reservoir. Tidal energy extraction requires a strong ocean effect and a natural resonant inshore configuration to make it work most efficiently and economically. The energy is as predictable as the state of the ocean tide at any instant.

Tidal energy extraction appears to be less demanding on advanced technologies than other energy sources; however, it highly depends on natural processes. Just as hydroelectric power depends on natural differences in the terrain elevation, tidal power depends on the natural configuration of inshore geological features. Few coastal areas exist where conditions combine to produce the degree of resonance required. Natural sites and celestial forces appear to favor the development of tidal power systems within latitudes of 50-60. Major tidal power development sites around the world are listed in Table 2.[19]

Table 2

Major Tidal Power Developments

Country	Location	Mean Tide Range (M)	Output (MW)	Initial Operation
China	Shashan	5.1	0.04	1959
France	La Rance	8.5	240.0	1966
USSR	Kislayan Gulf	3.9	0.4	1968
China	Jingang Creek	5.1	0.165	1970
China	Yuepu		0.15	1971
China	Ganzhutan		5.0	1974
China	Haishan		0.15	1975
China	Liuhe		0.15	1976
China	Beisakou		0.96	1978
China	JiangxiaCreek	5.1	3.2	1980
Japan	Kurushima		0.002	1983
Canada	Annapolis Royal	7.1	19.1	1984
China	Xingfuyang	5.1	1.28	1989
Canada	Bay of Fundy	15.2	1428.0	Proposed
Canada	Minas Basin	15.2	5338.0	Proposed
USA	Maine-Cobscook	5.4	300.0	Proposed
USA	Alaska-Cook Inlet	9.4	1440.0	Proposed
UK	Severn Barrage	11.0	7200	Proposed
UK	Mersey Barrage	6.5	620	Proposed
India	Gujurat	12.4	1100.0	Proposed
Kaea	Garolim-Inchon	4.8	480.0	Proposed
USSR	Mezenskaya	20.0	15,000.0	Proposed
Argentina	Puerto Gallegos	7.7	400.0	Proposed
Australia	Walcott Inlet	12.0	1300.0	Proposed

There are very few tidal energy power stations operating in the world today. The four countries with functioning systems are France, the Soviet Union, China, and Canada. These countries have been the most actively involved in the study of tidal energy conversion. The total power generated by these systems is about 263 MW. The La Rance tidal power station on the west coast of France, with an installed capacity of 240 MW, is the world's largest. Construction began in 1961 and was completed by 1968. The powerhouse is 390 meters long, housing 24 10-MW turbine units. The plant has been operational since 1968 with an outstanding 95 percent availability. In 1968, the Soviet Union put into operation a 400-kW pilot plant in Kislayan Gulf, called the Kislogubskaya pilot plant; it pioneered floating construction techniques. In 1985, the Soviet Union announced plans to build a tidal plant on the White Sea coast with a generating capacity of 15,000 MW. Called the Mezenskaya plant, it is still in the preliminary stages of development. In China, tidal energy was first reported in 1959 with the installation of a 40-kW plant located in Shashan. A 165-kW tidal plant was built in 1970 in the Shandong Province on the

Jingang Creek. In May 1980, China's first two-way tidal plant, rated at 500 kW, began operating on the Jiangxia Creek near the Zhousan Islands. This plant was later expanded to 3.2 MW in 1986. The Canadian tidal power project is the 20-MW plant at Annapolis Royal, Nova Scotia, built by the Nova Scotia Power Corporation. Located on the Annapolis River near its outlet at the Bay of Fundy, the plant contains a single Straflo hydropower turbine and has been operational since 1984. Presently, Canada is investigating the potential of such turbines for larger scale installations in the Bay of Fundy, and for low-head, run-of-the-river developments.

Environmental effects can be expected from the development of tidal power plants. Potential effects would be very site-specific and grouped into categories based on the physical changes brought about by construction and operation of the plant. These include the physical presence of the dam, changes in water level, changes in flow patterns and current velocities, and changes in sediment patterns. During construction, dredging, blasting, and placement of rock fill or concrete structures will impact benthic habitats, increase turbidity (thus affecting organisms within the water column), and may restrict navigation. These impacts would be short-term and local, and would vary depending on whether float-in or cofferdam construction were employed. Once constructed, the physical presence of the dam represents permanent changes which could affect recreational use of the water and impoundment, navigation, and fish passage and habitat. Locks can be used to assist navigation and, in some cases, navigation within the basin could be improved by higher average water levels. The opportunity to build a road across the dam would be a major positive benefit, especially at large sites. The generally smaller tidal ranges, as discussed below, would offer increased opportunity for recreational boating. Because of the large volumes of water involved, entrainment of fish in plant turbines could be a problem. For example, shad migrate through the Bay of Fundy and concern over their entrainment has been cited in regards to potential Bay of Fundy tidal power projects.[1]

The United Kingdom conducted a design study of a tidal plant at Langstone Harbor, Hampshire that had a 3-meter mean annual tidal range generating 24.3 MW on the ebbtide cycle. Construction cost was estimated at $2,813/kW and electricity produced at $0.162/kWh in 1986 dollars. In constant 1990 dollars, this equates to about $3,511/kW and electricity cost at $0.197/kWh.

Compared to other ocean energy technologies, tidal power is relatively well developed. However, there are three areas in which research and development could enhance the performance and reduce the costs of tidal power: sluice gate design, development of float-in construction techniques including construction of a pilot plant, and improved turbine design. Construction experience with the Delta Works, a system of tidal barrages and sluices along the Dutch coast, should prove useful in guiding development of float-in construction techniques. Recent experience with the Straflo turbine operation at Annapolis Royal should be useful in evaluating potential improvements in turbine technology.[1]

Wave Energy

Ocean wave energy conversion technologies utilize the kinetic energy of ocean waves to produce power. Wave energy is a potential environmentally benign and renewable energy resource. The general approaches to converting wave energy into electricity can be broadly categorized by means of deployment and means of energy extraction and conversion. Means of deployment include floating deep-water technologies and shallow-water, fixed-bottom technologies. Means of energy extraction and conversion include mechanical cams, gears, and levers; hydraulic pumps; pneumatic turbines; oscillating water columns; and funnelling devices. Table 3 describes the size, location, and technology of a number of active or proposed wave energy facilities. At present, five wave energy systems generate a total of 535 kW and two more commercial systems will be operating by 1992.

Table 3

Major Wave Energy Developments

Country	Locations	Wave Power (kW/m)	Technology	Rating (kW)	Comments
Norway	Toftestallen	7.0	Multiresonant OWC	500	Operated ('85-89)
Norway	Toftestallen	7.0	Tapered Channel	350	Operating ('86)
Norway	Java	20-25	Tapered Channel	1,500	Operation C92)
Norway	Tasmania	30-32	Tapered Channel	1,500	Operation ('92)
Denmark	Hanstholm	9.0	Heaving Buoy	45	Tested 1990
UK	Islay	5-15	Shore-based OWC	75	Operation ('91)
UK	Mauritius		Shore-based OWC	500	Proposed (Inactive)
India (UK)	Madras		Offshore OWC	5,000	Proposed (Inactive)
India	Southwest Coast		Offshore Caisson OWC	150	Pending
Japan	Yura		KAIMEI, Barge-mounted OWC	125	Operated ('78-80 & '85-86)
Japan	Sanze		Shore-based OWC	40	Operated C83-84)
Japan	Sakata Port		Breakwater OWC	60	Operating ('89)
Japan	Kujukuri		Shore-based OWC	30	Operating ('88)
Japan	Mashike		Breakwater Pivoting Flap	20	Operating ('83)
Sweden	Gottenberg		Heaving Buoy	30	Tested 1989
Spain (Sweden)	Atlantic Coast		Heaving Buoy	1,000	Proposed (Inactive)
Portugal	Azores		Shore-based OWC	300	Proposed
USSR	Makhachkala		Heaving Buoy	50	Tested
China	Dawan Island		Shore-based OWC	8	Constructing
USA	Puerto Rico		Heaving Buoy Desalination Project	350 (GPD)	Operating (89)

*OWC = Oscillating Water Column

Sources: Hay, G.A., 1990' and SEASUN Power Systems, 1990

The Japanese government has had a very active wave energy research and development program for many years. Applications under investigation range from wave power generators for lighthouses and light buoys to wave pump systems, ship propulsion, and energy for road heating, heat recovery systems, and fish farming. Several technologies have been examined by both government and industry, including floating terminator-type wave devices, fixed coastal-type wave power extractors, and applications of oscillating water column turbines. The most well known project, supported by the International Energy Agency, was the KAIMEI, a 500-ton, barge-like platform containing about ten oscillating water columns. Wave action produces oscillations of the water column that produce pneumatic power which is converted to electrical power via air turbo-generators.

The Indian government has investigated the potential of oscillating water column plants and studied the feasibility of building a 5-MW plant in a new harbor breakwater near Madras. Presently, a 150-kW demonstration plant using a Wells turbine-generator is under construction at a fishing harbor near the port of Trivandrum.

The United Kingdom wave energy program was initiated in 1974. Ongoing development projects include wave-powered desalination and pumping, investigation of the use of a Wells turbine in naturally-formed rock gullies, construction of a 75-kW prototype wave power plant on the Scottish Island of Islay, production of wave-powered turbine generators for navigational buoys in Northern Ireland, and development and model testing of a small-scale Sea Clam wave energy converter at Loch Ness by Coventry Polytechnic.

Norway has conducted an extensive wave power program since 1975. In the 1980s, these efforts included the installation by Kvaerner Brug A.S. of a 500-kW prototype wave power system, called the multiresonant oscillating water column (MOWC), on the west coast of Norway. Operational since November 1985, the plant was swept off its foundation and destroyed during a severe storm in January 1989. In 1986, the Norwegian firm NORWAVE A.S. installed a new system called TAPCHAN, a tapered channel wave power plant in Bergen, Norway, that produces 350 kW of power. Typically, a tapered channel is carved out of a rocky coastal area, using shaped charges, if necessary. The taper can handle a wide spectrum of wave lengths efficiently. As a wave passes through the tapered channel, its wave height is gradually increased as the channel narrows. The wave then spills over into a reservoir where it is stored and subsequently passes through a low-head Kaplan water turbine to generate electricity. NORWAVE A.S. is developing two commercial TAPCHAN systems: one to be installed in Java and the other in Tasmania. Each system will produce about 1.5 MW of power. The construction costs range from about $2,000/kW in Java to $3,550/kW in Tasmania and the systems are expected to produce power at rates of about $0.05-0.10/kWh.[17]

In Sweden, use of a heaving buoy as a wave energy converter has been extensively studied. Field tests of a 30-kW prototype hose-pump device have recently been completed off Sweden's west coast and there was a proposal for a 1-MW pilot plant to be installed off the Atlantic coast of Spain. Pharos Marine in

United Kingdom has developed a wave-powered navigation buoy using the same concept. In the Soviet Union, testing is underway for a 3-kW wave power plant and a 50-kW inertial wave power unit at Makhachkala in the Caspian Sea. In the United States, wave energy activity has included research and development of the McCormack pneumatic turbine; prototype testing of a heaving and pitching circular float, tandem-flap system, and contouring raft device; and research on a heaving buoy type, wave-powered desalination system in Puerto Rico.

The impact on the environment of wave energy conversion is strongly dependent on the scale of the activity. When a modest project is proposed, where the average power delivered to the grid is 40-100 MW, the impacts are likely to be small. However, there will be community resistance should recreational sites be compromised. If a large scheme delivering several thousand megawatts is proposed, the impacts are obviously expected to be larger, and may not be benign.

The conversion of wave energy to electricity may be expected to influence the coastal wave and current climate, the populations of fish and marine mammals, the navigation of ships, and the visual environment. A large wave power conversion system would modify the local wave climate. A reduction in the wave energy arriving at the shores can change the density and balance of species of organisms around the coast, and may modify the deposition of sand on the beaches. The wave energy conversion devices might be expected to have an influence on the populations of fish and marine mammals. Bottom feeding fish and shellfish, such as lobster and crab, are likely to be unaffected. Fish and marine mammals that spend much of their life near the surface require more consideration. Salmon, members of the herring family, and even sea lions have been mentioned as species that will have to be evaluated when impacts of large-scale wave energy conversion systems are considered.

Wave energy converters placed in or near shipping lanes would present a hazard to shipping because their relatively low profile would make them less visible to sight and radar. The devices would have to be properly marked, and navigation channels would have to be provided through large arrays of the converters. Mooring failures resulting in drifting of the floating devices would provide an additional hazard to navigation and shoreline structures.

The visual effects of wave energy will depend on the site selected, size of the floating platforms, the length of the array, distance offshore, and method of cable transmission. Shore-based systems such as TAPCHAN may be blended into the coast and require a relatively low-profile reservoir ashore to provide the necessary head of water. Depending on the power, the profile of an array can be barge-like (e.g., the KAIMEI Project) and could require a long line of such structures. The visual effect will depend on how far offshore and the impact is difficult to generalize because each configuration and installation plan will differ from one location to another.

A wave energy system designed for Lewis, Outer Hebrides Islands, is used as a base case in Table 4. The wave source is estimated at 48 kW/m mean annual power. The system is based on the SEA CLAM design in a circular-spine configuration to produce 2.5 MW. Construction cost in 1990 was estimated at $1,500/kW with the cost of electricity produced at $0.126/kWh. Wave energy conversion devices can provide additional benefits such as providing calm seas behind by the breakwater effect; and co-generation of freshwater by forcing sea water through a semi-permeable membrane.

Table 4

Comparison of Small-Scale Ocean Energy Systems for Coastal and Island Communities in the United Kingdom

	Wind	Wave	Tide
Location:	Brennan Hill, Ayrshire	Lewis, Outer Hebrides Islands	Langstone Harbor, Hampshire
Resource:	10m/sec mean annual wind speed	48 kW/m mean annual wave power	3.13m mean annual tidal range
Technology:	horizontal axis, twin-blade	SEA Clam (circular-spine)	single-effect, ebb-generation
Plant Dimensions:	60m rotor diameter, 45m high tower	60m diameter waterplane area, 6.25m draft	550m long barrage, 19 million sq. m reservoir
Plant Capacity (MWe):	3.7	2.5	24.3
Capacity Factor:	29%	22%	25%
Construction Cost ($/kW):	1,585	1,500	2,813
Cost of Energy (¢/kWh):	9.0	12.6	16.2
Year of Estimate:	1986	1990	1986

New configurations of wave energy conversion devices are continually being designed at various research centers throughout the world. At present, it is very difficult for companies to obtain an accurate assessment of the performance and energy cost of such devices. There is a need to support field-test facilities that are equipped to evaluate various wave conversion devices and their performance claims.

Considerable wave data has been collected but not evaluated. Wave climate data is needed in a form suitable for the designers of wave energy systems, for potential sites. Methods exist for extrapolating and interpolating data collected at particular locations to provide wave climate information. Such a data base would be invaluable not only to the designers of wave energy devices, but to the entire ocean engineering community. There is also a need to provide the technology for reliable and cost effective moorings and riser cables for floating wave energy devices. This problem exists for all types of ocean engineering projects that use floating, moored platforms.

Current Energy

While the kinetic energy of river currents has been used from medieval times to produce power using simple water turbines, the proposed application of current turbines in the oceans is a comparatively recent development prompted by the observations of mariners and oceanographers of the swiftly-flowing current in some regions. The Gulf Stream, or more specifically, the Florida Current, is of particular interest because of its high current velocity and proximity to large population centers on the Florida coast. The Florida Current is particularly strong off the city of Miami, and ocean current turbines have been proposed to exploit this resource.

The performance of an ocean current turbine is similar to the performance of a wind turbine. The ocean or wind turbine transforms a proportion of the kinetic energy of the flow into mechanical power. A small ocean turbine was demonstrated in 1985 in the Florida Current. The unit was suspended from a research vessel at a depth of 50 meters and developed approximately 2 kW. The project was privately funded, and a proposal made to design and test 100-kW and 1 to 2-MW units of a similar design.[1]

In addition, a 20-kW prototype turbine, designed by UEK Corporation, is under research and development, for which testing is planned in New York City's tidal East River. Since 1979, Canadian researchers at Nova Energy, Ltd. have been developing large Darrieus-type vertical axis turbines for hydropower applications and are presently completing testing of a 5-kW prototype. Australian current energy conversion units designed by Tyson Turbines Ltd. are small- to medium-size modular devices capable of producing an energy output of more than 670 kW depending on depth and stream velocity. These units are commercially available for a variety of applications and have been demonstrated in many countries including Australia, the Philippines, Mexico, the United States, and Canada.[11]

The Gulf Stream carries 30 million cubic meters of water per second, more than 50 times the total flow in all of the world's fresh water rivers; the surface velocity sometimes exceeds 2.5 meters per second. The extractable power is about 2,000 watts per square meter and would, therefore, require extremely large, slow-rotating blade turbines operating like windmills. The total energy of this Florida current is estimated to be about 25,000 MW.

In 1979, the Aeroenvironment Company conducted a conceptual design study (Coriolis Project) based on installing very large diameter turbines (referred to as Coriolis turbines) in the Gulf Stream. Energy calculations indicated that an array of 242 large turbines, each about 170 meters in diameter, moored in the Gulf Stream in an array occupying an area of 30 kilometers cross-stream and 60 kilometers downstream would produce about 10,000 MW. This is the energy equivalent of about 130 million barrels of oil per year. Cost estimates indicated that each unit could be built and installed at about $1,200/kW in 1978 dollars. Including capital, operating, maintenance, and fuel costs, power is delivered at about $0.040/kWh in 1978 dollars. These figures assumed a plant factor of 57 percent, which is computed in a way similar to that used for wind turbines, by considering the seasonal variation in the current, plus a two-week annual maintenance shutdown. The Coriolis system is an environmentally benign, cost-efficient method of extracting energy from a renewable source.[6]

The environmental effect of an array of Coriolis ocean turbines on the Florida Gulf Stream current has been investigated for several models. The results showed that for an annual average extraction of 10,000 MW, the reduction in speed of the Gulf Stream is estimated at about 1.2 percent, much less than its natural fluctuation. Further calculations indicated that any heating effects resulting from turbulence in the wake of the turbines would be very small.[6] A 1-meter diameter turbine with compliant blades and rim-driven system was constructed and demonstrated in a water flume. No further research and development was conducted. However, more research is needed to provide greater confidence in technical and economic feasibility in constructing, installing, and mooring very large turbines of the size proposed. Current energy systems do not appear to be ready for commercial application at this time.

Salinity Gradient Energy

A large unused source of energy exists at the interface between fresh and salt water, and the extent of energy depends on the salinity gradient. In extracting this salinity gradient energy, the heart of most systems is a semi-permeable membrane that allows water, but not dissolved solids, to pass through the membrane. With fresh water on one side and salt water on the other side of the membrane, the force of the fresh water through the membrane creates an osmotic pressure difference. As fresh water permeates through the membrane, a head of water is developed with respect to the salt water, and a turbine can be used to extract energy from the water flow.

The energy difference that exists between fresh water and salt water depends on the salinity gradient and is represented thermodynamically as the difference in the free energy at the temperature of the two flows of water. The power that could be produced from any salinity gradient device increases with salinity difference and would be particularly effective when the salt water is a dense brine. Power may be generated from the free energy difference in various ways: in a hydraulic system using the difference in osmotic pressure between fresh water and sea water; as electrical energy in a reverse electrodialysis cell; or in a vapor turbine utilizing the difference in vapor pressure between fresh water and sea water. An additional method of using the free energy in a salinity gradient has been devised utilizing the extension and contraction of special fibers induced by changes in salinity.[1]

The potential energy available from major sources of salinity gradients throughout the world is shown in Table 5. To place this in perspective, the projected U.S. energy consumption for the year 2000 is about $6x10^{11}$ watts. Note that Table 5 does not include the potential for producing power by mixing fresh or sea water with salt marshes or other major salt deposits. The extent and distribution of these resources have not been addressed. Also, there may be considerable potential for producing power with small units using evaporation ponds. Although energy from salinity gradients cannot by itself provide energy independence, it has the potential for ultimately making a substantial contribution, depending on its economic competitiveness.

Table 5

Potential Power from Salinity Gradients

Source	Country	Flow Rate (10^4 m/sec)	Pressure (atm)	Power (10^6 kW)
Run-Off	Global	110.0	24.0	2,600.0
Run-Off	USA	5.3	24.0	130.0
Amazon River	Blazil	20.0	24.0	470.0
La Plata-Parana River	Argentina	8.0	24.0	190.0
Congo River	Congo/Angola	5.7	24.0	130.0
Yangtze River	China	2.2	24.0	52.0
Ganges River	Bangladesh	2.0	24.0	47.0
Mississippi River	USA	1.8	24.0	42.0
Salt Lake	USA	0.0125	300.0	1.8
Dead Sea	IsraeVJordan	0.0038	300.0	1.8
Wastewater to Ocean	USA	0.05	22.5	1.1

The application of energy from salinity gradients should be relatively simple once the power has been generated. The most promising concept for energy conversion would use the osmotic pressure head to drive turbines which would produce electrical power in the same manner as the production of power from existing hydroelectric systems. This technology is well developed, and the conversion efficiency of a hydroturbine-electric generator system is about 90 percent. If sea water were used in a salinity gradient power system, the power would likely be generated in coastal zones. These zones are generally the most heavily populated and the electricity produced could be tied directly into existing power supply grids.[7]

The development of candidate systems for the production of power from salinity gradients has not progressed far enough to provide an accurate economic assessment of system types and configurations. However, general considerations can be presented which point to one concept which may be promising if the salinity gradient is very large, such as where the Jordan River flows into the Dead Sea. An analysis and preliminary experiments for a 100-MW plant at the mouth of the Jordan River indicate that power could be produced at a cost of $0.072/kWh in 1976 dollars.[7]

Although this cost is more than double the cost of electricity from a coal-fired power plant, dramatic improvements may be possible for the salinity gradient power plant with improvements in semipermeable membranes. A brine such as that which exists at the Dead Sea or Great Salt Lake can be used to produce a greater salinity gradient. Another difficulty is that geographical areas with naturally occurring bodies of high salinity brine are usually deficient in the fresh water needed to provide the salinity gradient. However, it may be possible to use sea water or other brackish water as the low salinity permeate. It may even be feasible to create a renewable energy resource by using sea water in evaporating ponds in a coastal area to produce the high salinity brines which would be mixed with the low salinity sea water permeate.

In an evaluation of the subsystems and components which would comprise a salinity gradient power plant, it becomes apparent that the semi-permeable membrane is the major technical problem. In all other respects, the plant would draw upon well established technical capabilities which have little potential for marked improvements. The membrane, however, has a very significant potential for improvement in terms of cost and performance and, at the same time, is the major controlling factor in determining the power output of a plant operating with a specified salinity gradient. The major problems with respect to semi-permeable membrane development are flux, fouling, salt rejection, life expectency, and cost. The production of power from the salinity gradient between fresh water and sea water will not be economically feasible unless the membrane flux can be improved by an order of magnitude and the requirement for pre-treatment of the water can be virtually eliminated.

Wind Energy

The wind at many island and coastal sites is both strong and persistent. Such sites may be suitable for placing arrays of wind turbines to generate electricity. Some studies of ocean wind turbines have been conducted in the U.S. and in other countries. Also, there is international cooperation in the development of ocean wind turbines through the International Energy Agency. As part of that program, some European turbine systems are being designed and it is intended that the offshore support structures will be evaluated using computer analyses developed in the United States.

Probably the most detailed engineering evaluation of ocean wind turbines was conducted in the U.K. for a large array of turbines designed for an annual mean wind speed of 8.5 meters/second at a site about 20 miles off the east coast of England. The proposed wind turbines were 100 meters in diameter and the designs were based on a conventional wind turbine 60 meters in diameter. An array of 320 wind turbines were to be placed on individual towers, which were 86.5 meters tall, in water 20 meters deep. The predicted energy costs for the British study, in 1984, were 5-9 pounds/kWh, or about $0.075-13.5/kWh. The cost of electrical energy from offshore wind turbines was predicted to be twice that of onshore wind turbines.[1] Wind farms located in offshore waters would increase the capital cost of construction by adding the cost of larger seaworthy towers and foundations. The cost for offshore maintenance would also be higher.

As of May 1989, the American Wind Energy Association (AWEA) estimated that there were more than 1,600 MW of wind power on line in the U.S. Over 90 percent of the machines are at three California sites (Altamount Pass, Tehachapi, and Palm Springs), with 16,000 wind machines generating about 2 billion kWh of electricity in 1988, an energy equivalent of 3.5 million barrels of oil. Hawaii ranks second, with about 34 MW of wind power on line. The greater capacity of wind power produced in California is mainly attributed to state tax credits (since abolished). Economic factors make the difference.[8]

The cost per kWh is dropping rapidly (as low as $0.07-0.10/kWh) and the projected cost with the advanced midsize wind turbine generator is $0.04-0.06/kWh. Improved reliability (95 percent or better availability factor), better materials, and other improvements to newer machines have resulted in further reducing operating and maintenance costs to under $0.05/kWh and a capital cost of less than $1,000/kW in 1989 dollars. Due to the variability of the wind source, utilities must limit the dependency on wind power applied to the power grid. In the future, wind energy-related energy storage systems such as flywheels, batteries, pumped-storage hydroelectric, hydrogen, compressed air, and so forth coupled with computer control system(s) and advanced power electronics will diminish variability.[8]

AWEA's newsletter (July 10, 1989) pointed out that: "A typical 100-kW wind electric turbine by U.S. Windpower weighs about 7 tons, and if it offsets coal-fired electric generation, would prevent nearly two and a half times its own weight each month in emissions of carbon dioxide (CO_2), the primary gas implicator of global warming." The article also pointed out that California's 16,000 wind machines offset 11 million pounds of air pollutants per year.[8]

Public acceptance of wind energy conversion systems is an important consideration in planning for the widespread application of wind energy. Studies have shown that the environmental impact of such systems is relatively small compared to conventional electric power systems. Wind-powered systems do not require the flooding of large land areas or the alteration of the natural ecology, as for hydroelectric systems. Furthermore, they produce no waste products or thermal or chemical effluents, as fossil-fueled and nuclear-fueled systems do. A wind farm of many rotor blades could have some impact on the local bird population.

Conventional wind turbine systems that generate several megawatts of power require large exposed rotors on the order of 60 meters in diameter, located on high towers. The rotors of such systems; being passive, are practically noiseless. However, special precautions will be necessary to prevent them from causing interference with nearby TV or radio receivers, and some safety measures may be required to prevent damage or injury from possible mishaps in cases where there is danger that the rotors might break or shed ice.

The only other concerns with conventional wind machines are those of aesthetics. Large numbers of units and interconnecting transmission lines will be required in the future if such systems are to have any significant impact on U.S. energy demands. Particular attention is being given, therefore, to the development of attractive designs for the towers, rotors, and nacelles of these conventional systems to avoid "visual pollution."[3] Depending on the location and proximity to living and recreation spaces, large fields of towers and rotors may be visually offensive.

There appear to be important advantages to using wind-derived energy in combination with energy derived from other sources, such as conventional fuels, sunlight, ocean thermal differences, bioconversion fuels, etc. Since the wind blows intermittently in most locations, there may be a need to store wind energy over long periods of time, perhaps up to 10 days or more, if the energy is being used for isolated applications requiring continuous power. The cost of providing sufficient storage capacity for such applications can be reduced if the wind-derived power is interconnected with other sources of power. Because in most locations the wind often blows when the sun is not shining, and vice versa, a system using wind energy collectors and sun energy collectors (solar photovoltaic arrays or other solar thermal collectors), in combination, can be expected to require less energy storage capacity than systems that use these types of collectors singly.

FUELS AND ENERGY-ENHANCED PRODUCTS FROM THE SEA

While considerable solar energy is stored within tropical oceans, these regions generally are not centers of industrial development, nor significant energy markets. Thus, for offshore ocean power production to prove useful and competitive in the world energy market, it is necessary to formulate efficient and economical means to redistribute the energy generated by these technologies from areas rich in ocean energy resources to areas of high energy consumption. This need has sparked interest in the development of transportable fuels and other products which take advantage of power produced by ocean energy conversion systems in manufacturing processes. The Department of Energy's recent review of the concept provides a concise assertion: "The greatest potential for OTEC is to supply a significant fraction of the world's fuel needs using large plantships to produce hydrogen, ammonia, or methanol."(The Potential of Renewable Energy: An Interlaboratory White Paper, Idaho National Engineering Laboratory, Los Alamos National Laboratory, Oak Ridge National Laboratory, Sandia National Laboratory, Solar Energy Research Institute, March 1990.)

Substantial effort has been expended thus far to improve isolated ocean energy conversion technologies, yet very few have reached the commercial stage. One major reason for their lack of commercial success is that the isolated technologies have not capitalized on ancillary products or on inputs that might synergistically integrate these isolated technologies into complete systems, as depicted in Figure 1. It is this integration that will make the development of ocean resources economically viable in the future.[16]

If the ocean is ever to develop into a major supplier of energy fuels, multi-product systems will be the primary inducement. Many tens of thousands of ocean energy megawatt equivalents can someday power floating cities and industrial platforms for strategic metals, transportation fuels, chemicals, and other products.

The commercial success of these enterprises will almost surely depend on total system integration. For example, a grazing platform which harvests and processes seabed ores, using OTEC electricity, and returning wastes to the ocean floor, could well turn out to be the only acceptable option for strategic metal production. Likewise, a marine biomass plantation encircling a floating methanol production facility in the open ocean, utilizing upwelled deep ocean water, creating new fisheries, while perhaps enhancing the atmosphere by utilizing carbon dioxide, could be much more efficient and economical than non-integrated ocean or land-based enterprises.

During the next decade, much of the research required to advance the science and engineering relating to production of fuels and energy-enhanced products from the sea can be performed at land-based facilities such as at the Natural Energy Laboratory of Hawaii and the Shikoku Laboratory of the Japan Marine Science and Technology Center, both of which feature pipes that bring deep, cold water to the surface. However, prototype experiments will also need to be performed on the open ocean to test concepts and gain the confidence of the financial sector.

The National Science Foundation sponsored a workshop in 1989 on "The Ocean Enterprise." Recommended was a series of OTEC-related projects leading to a 500-MW ocean mineral platform combining OTEC and seabed ore processing by the year 2000, and a 1000-MW Pan American complex featuring multinational cooperation and a full range of co-products at a cost of $10 billion by 2010. If global warming becomes a serious matter, nuclear power plants continue to face societal acceptance problems, mineral shortages occur, and the commercial equivalent of the National AeroSpace Plane—which will be powered by liquid hydrogen — flies, OTEC should be in a prime position to provide fuels from the sea by year 2020.

INTERCOMPARISON OF OCEAN ENERGY CONVERSION SYSTEMS AND FOSSIL-FUELED POWER PLANTS.

Table 4 provides a comparison of small-scale ocean energy systems for coastal and island communities in the United Kingdom. This comparison shows that the capital costs for construction in 1990 constant dollars range from about $1,500-3,285/kW for the small-scale wave, wind, and tidal power, but the cost of electricity produced is about the same for wind and wave and almost double for tidal. However, at this relatively early stage of development, these differences are not very great.

By 1992, over 3.5 MW of wave power will be on-line with energy utilization costs that are economically competitive, especially for the island market. Most of this wave power will be derived from the TAPCHAN System developed and commercialized by NORWAVE A.S. The oscillating water column and the heaving buoy are competing systems. Wave power capital costs range between $1,500-3,550/kW and cost of electricity produced from about $0.07-0.13/kWh. Environmental impacts of wave energy differ based on their location, e.g., the shore-based TAPCHAN involves coastal land use for the funneling system and reservior, but has minimum impact on marine life and nearby coastal activities; the near-shore caisson-contained line of wave energy converters can create calm seas behind and affect sediment transport and associated marine life; and the far offshore line of wave energy converters can create an obstacle for commercial fishermen, and also require navigation markers for marine transportation.

Wind farms on land, as demonstrated by over 1,600 MW on-line in the U.S. in California and Hawaii, have proven economic competitiveness and have coupled into the commercial electric power grid. The construction capital costs in the U.S. were about $1,000/kW and energy costs about $0.07-0.10/kWh and this is fairly close to the U.K. example in Table 4. Wind farms offshore are expected to cost more for installation and for offshore maintenance cost, but the cost of electricity produced would be close to costs on land. Environmental impact pertains mainly to use of large expanses of coastal land for a field of vertical towers, which may not be visually attractive from some perspectives.

Tidal power has been on-line for over two decades using conventional technology and has proven economic viability with energy costs varying, depending on the physical characteristics of the selected site. Environmental impacts will also vary from site-to-site depending on: the extent of alteration of the marine ecology by the controlled duirnal movement of water flowing through the turbines; and the extent of disruption to the multi-users and nearby inhabitants of the body of water involved.

As noted in Table 1, a considerable effort has been expended in advancing research and development of OTEC. Based on the available information, the construction capital costs (constant 1990 dollars) for OTEC range from about $16,260/kW for the 46-MW closed-cycle plant proposed for Hawaii to $22,570 for a small scale 1.15-MW open-cycle plant proposed for a Pacific Island. The cost of electricity in 1990 constant dollars is about the same. These costs do not reflect the potential of providing co-products such as freshwater and nutrients for aquaculture to offset these costs.

The economic competitiveness of ocean energy conversion systems versus fossil-fuel power plants is shown in Tables 6 and 7. Table 6 shows a comparison of a wave energy system versus a coal-fired plant in California. In 1990 constant dollars, the construction capital costs are about the same and cost of electricity is fairly close, considering the wave energy system is in its early stages of development. Table 6 also compares OTEC with a coal-fired plant, showing that construction capital costs and cost of electricity produced are about six times greater for OTEC, exclusive of the benefits of by-products. Table 8 illustrates dramatically the advantages of producing fresh water as an OTEC by-product.

Table 7 is a comparison of wave energy and OTEC versus an oil-fired plant for South Pacific Island sites. In the case of wave power for Tasmania, construction capital costs are much higher than the oil-fired plant in New Zealand; however, the cost of electricity produced is less than half the cost. The cost of OTEC construction capital costs are about 50 times greater and cost of electricity produced about two times greater than that of the oil-fired plant.

Table 6

Comparison of Ocean Energy with Coal: California & Hawaii

	California		Hawaii	
	Coal	Wave	Coal	OTEC
Technology	Pulverized Coal	Heaving Buoy	Fluidized Bed	Closed Cycle
Fuel Cost ($/106BTU):	2.05	N/A	2.05	N/A
Plant Capacity (MWe):	275	30	180	46
Capacity Factor (%):	70	29	85	
Construction Cost ($/kWe):	1940	2098	2131	12,203
Service Life (yrs):	30	30	40	35
Cost of Energy (¢/kWh):	6.9	13.1	5.9	25.5
Year of Estimate:	1987	1990	1990	1985

Table 7

Comparison of Ocean Energy with Oil: South Pacific Island Sites

	Wave	Oil	OTEC
Location:	King Island Tasmania, Australia	Steward Island New Zealand	Design Study
Technology:	TAPCHAN	Power Plant	Open Cycle
Fuel Source:	N/A	Bulk Diesel	N/A
Plant Capacity (MWe):	1.5	0.9	1.15
Capacity Factor (%):	68	34	80
Construction ($/kWe):	3550	449	22,570
Service Life (yrs):	40	20	30
Cost of Energy (¢/kWh):	6.7	13.6	33.1
Year of Estimate:	1990	1985	1989

OTEC plants that discharge large quantities of cold water could affect: the natural thermal and salinity gradients; levels of dissolved gases; composition of nutrients and trace metals; and water turbidity; and thus affecting the marine ecosystem. The effect on marine life will depend on the care taken to stabilize the discharge plume below the mixed layer to protect the thermal resource and reduce environmental effects. A more serious impact could occur in the event of an accidental spill of OTEC working fluids such as ammonia, freon, or some other environmentally hazardous fluid. Also, the use of chlorine as a cleaning fluid to reduce buildup of any organic film on the heat exchangers could be a problem. Research experiments have shown that the amount of chlorine needed for cleaning is diluted with sea water to safe levels before discharge.

Table 8

OTEC Market Penetration Scenarios[18]

Nominal Net Power (NWe)	Scenario Type	Scenario Reqts	Availability
1	Land-Based OC-OTEC with 2nd-Stage additional Water Production	• \$45/barrel of diesel • 1.6m³ water	South Pacific Island Nations by Year 1995
10	Land-Based (as above)	• \$25/barrel of fuel oil • \$0.85/m³water - or - • \$30/barrel with • \$0.8/m³water	American Island Territories and other Pacific Islands by Year 2000
40	Land-Based Hybrid (ammonia power cycle w/Flash Evaporator downstream)	• \$441barrel of fuel oil • \$0.4/m³water - or - • \$22/barrel • \$0.8/m³water	Hawaii, if fuel or water cost doubles by Year 2000
40	• Closed-Cycle Land-based • Closed-Cycle Plantship	• \$36/barrel • \$23/barrel	By Year 2005

• OC-TEC limited by turbine technology to 2.5 MW modules or 10 MW plant (with four modules)
• OC-OTEC or Hybrid (water production downstream of closed-cycle with flash evaporator)

CONCLUSIONS

As energy demands continue to increase in support of burgeoning populations and industry demands, a growing concern exists about the impact of fossil fuel combustion causing global warming and air pollution; extracting oil and gas, and oil spills; and dwindling supplies of oil and gas which may be exhausted by the middle of the 21st Century. Totally safe nuclear power would be an alternative, but society has not been receptive because of potential catastrophic failures and radioactive waste disposal. Relative to fossil fuels and nuclear power, ocean energy conversion systems provide an inexhaustible, nonpolluting source that has great potential as an alternate energy source to contribute to present and future needs with relatively minor impacts on the marine environment. Ocean energy can be extracted by converting the dynamic motion (kinetic energy) of wind, waves, and currents induced by solar winds; converting ocean thermal and salinity gradients; and converting biomass energy derived through photosynthesis. Technical feasibility, economic competitiveness with the cost of energy, and environmental impacts are the major determinants in realizing commercialization.

The comparison of ocean energy conversion systems and fossil-fuel plants discussed above indicate that energy derived from wind power, wave power, OTEC, and tidal power are economically competitive to fossil-fueled systems, considering their early phase of development and the potential by-products that can offset costs for OTEC and wave power.

It is fortunate that an initial need exists for small-scale ocean energy plants to satisfy the island market by providing a degree of energy independence, as well as some valuable by-products. As experience is gained and further cost reduction achieved, the systems can grow in capacity to satisfy an even larger market, eventually leading to larger coastal communities. Design studies have shown that costs will be further reduced by economies of scale.

The selection of which form of ocean energy conversion is most suitable will depend mainly on the particular needs of an island or region, the available ocean energy resource, and the geographical and geological characteristics of the site. Once that is determined and the technical requirements formulated, the system can be financed in many ways. To stimulate early commercialization and share in any risks, a public/private partnership between, for example, state/local government, local utility, and the constructing firm would be a good way to increase probability of success.

Ocean energy will provide much needed energy diversity in an environmentally acceptable manner to: phase in the replacement of dwindling supplies of oil and gas that could be severely depleted in three decades; and to reduce oil and gas usage due to its impact on global warming and air pollution.

The rationale for continued commercialization of ocean energy conversion systems is very compelling and essential to help meet societal needs in the 21st century.

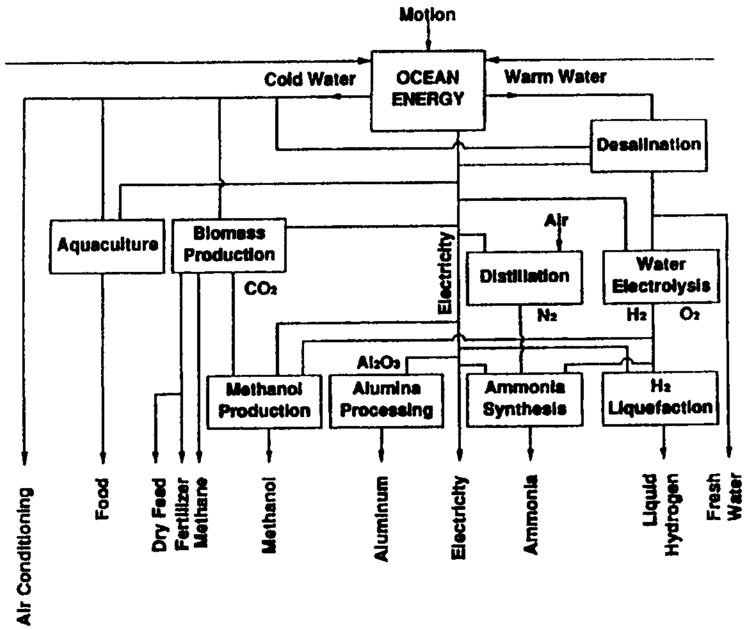

Figure 1. Integrated, multiple product ocean energy system

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A Proposal for the Refreshment of the Coastal Zone Utilizing Wave Energy

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ABSTRACT

Wave energy is a renewable and clean energy resource, its total amount is infinite in spite of low density of energy, and it can be utilized anywhere in the ocean coastal zone as the environmental problems of pollution of seawater and the sea bed become more serious year by year.

The authors have proposed a system which promises to be a more effective and more suitable utilization of coastal zones in the system. Wave energy is absorbed by the floating offshore wave power device "the Mighty Whale," through which the wave energy is converted to the energy of compressed air. Compressed air is transported into the enclosed bay with clean seawater, which can refresh the seawater and sea bed.

According to the discussion of the system, authors tried to design it and evaluate a rough construction cost. In this evaluation, the length of the Mighty Whale is assumed as 100m, and there are 9 units of the air compressor of 60 kW in rated power on it. This system has the capability to improve an area of 1 km square in the ocean by the airation and the clean seawater from the offing. Authors estimated the cost of this system will be about 1.8 billion Japanese yen.

Furthermore, the Mighty Whale has other characteristics. These are the effective behavior on the performance of dissipation of waves, and the possibility for the marine sports and amusement facility at the offing.

Consequently, the authors have come to conclude that the system for the refreshment of enclosed oceans should utilize the wave energy for human beings in earth's future.

International Perspectives on Coastal Ocean Space Utilization
Phyllis M. Grifman and James A. Fawcett, Editors

INTRODUCTION

The 35th President of the U.S.A., J.F. Kennedy, stated that the ocean is the last frontier for human beings in the universe because of the huge resources at stake, such as numerous life forms, mineral resources, ocean energy resources and ocean space. Still now, the situation is not changed. Since people face numerous serious problems for our resources at the moment, we should continue to make efforts for the development of the ocean in spite of many difficulties.

However, when we pursue a program of ocean development, we have to consider ocean and global environmental problems. It is a matter of course to prevent or reduce pollution in sea water, in mud and sand seabeds and even in the air. Furthermore, we need to be careful of the ecosystem of the ocean and the view of the ocean also. Consequently, if we can discover problems in the early stages of the project for ocean development, we should stop and change our course.

For instance, in order to refresh the coastal zone, current methods utilize "exchange of sea water," or "dredging work." However, such methods require energy, and if such energy is supplied by fuel, coal or a nuclear power station, these power stations may cause "new" pollution for the global environment. The oceans must be kept clear and must not generate any pollution. Consequently, energy for the refreshment of the ocean environment must be supplied from an ocean natural energy power station.

To date, the authors continue to develop a wave power device, and are carrying out research on the system of this device combined with a system for refreshment of the coastal zone environment. Fortunately, the authors have succeeded in developing a unique and high performance floating wave power device, "the Mighty Whale." In this paper, the general concept and its possibility for practical use of the total system using "the Mighty Whale"[1] are discussed, as well as the performance for refreshment and a rough estimation of the cost for construction.

UTILIZATION OF WAVE ENERGY

Characteristics of Wave Energy

When we stand at any seashore, we can see waves, which means that we have a possibility for utilization of wave energy at any seashore. However, we need to consider the quantity and quality of wave energy and the cost for its utilization. In spite of the advantage of wave power, such as clean and infinite resources, it has been pointed out that the power changes every moment, and the total amount of power extracted by one power unit is not very much in comparison with the fuel or nuclear power station.

As the authors described in the introduction, a wave power plant does not cause any pollution and it is the most suitable power plant for supply of energy in the ocean through the long term. If we can discover and succeed in developing the way to store this energy cheaply and easily in the ocean, the problem which is the last "hurdle" for its practical use will be solved.

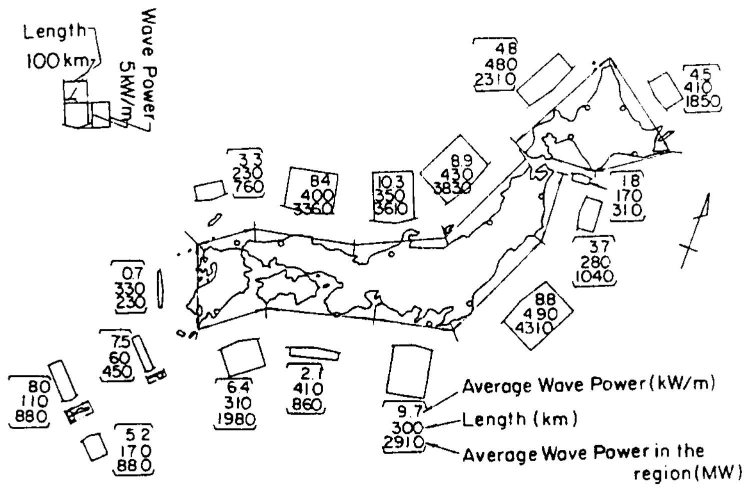

Figure 1. Wave power distribution around Japan

The wave power at seashores around Japan is shown in Figure 1;[2] although the average value of wave power fluctuates seasonally, the annual average power per unit length of shoreline around Japan is about 6 kW/m, and it is about 7 kW/m on the Pacific coast. At the coast of the Japan Sea in winter, wave power is more than 20 kW/m. The wave power becomes larger at the offing of ocean. Since the total length of shoreline of Japan is about 30,000 km, we can select the optimal location for the wave power utilization.

Conversion of Wave Power to Compressed Air Power

Recently, the large-scale energy storage method "the Compressed Air Energy Storage" has attracted attention. This is the system to store compressed air in an underground air tank for the purpose of adjustment to the optimal energy supply for a nuclear power station. The compressed air is generated at night using energy from the grid, and it generates the electric power by a gus turbine generator in day-time for supplying the energy to the grid.

Kadoyu and others paid attention to this system for the application in the ocean,[3] because the ocean has huge space and water pressure in spite of severe circumstances such as waves, current, tide, wind, salinity, bio-fouling and others. Fortunately, after general research on this sytem in the ocean, they reach the conclusion of possibility and several merits of this system.

By the way, if we can store compressed air in the ocean, we can utilize it not only for the generation of electric power but also for the refreshment of the coastal zone and "aquaculture." It is neccessary to increase the dissolved oxygen in seawater or to exchange seawater by the transportation of seawater from the offing for the refreshment.

Regarding this system, seawater is transported with compressed air as a mixed fluid of liquid and air just the same as the "air lift" method which is proposed as the techology for the mining of manganese nodules from the sea bottom. As for the air transported to near shoreline, it is discharged at the sea bottom for the generation of air bubbles to increase oxygen in seawater, that is, "airation."

The compressed air is generated by the compressor coupled to the air turbine, which is installed on the wave power device and rotates by the air flow generated by the air chamber of the Oscillating Water Column (OWC) type wave power device, as shown in Figure 2. The optimal matching between the compressor and the air turbine is one of the themes of the research and development on this system. In this report, details are not discussed; however, the authors guess that the ordinary compressor and air turbines may be available.

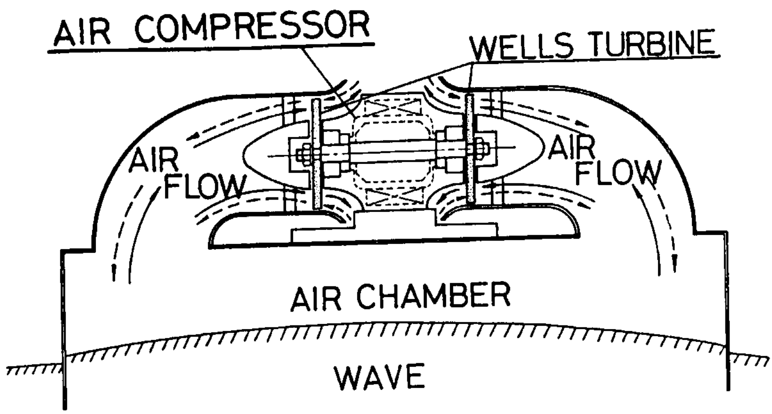

Figure 2. A scheme of wave power conversion system of Oscillating Water Column type wave power device

Multi-Purpose Utilization of the Wave Power Device

Since the wave power device can absorb wave energy, it means that the wave power device can dissipate the wave and create the calm sea area behind the device also. However, the performance for wave dissipation of the floating wave power device, such as "the Mighty Whale" shown in Figure 3, is not so good in comparison with the fixed type device, especialy in waves of long period such as storm waves.

From the point of view of the effect on coastal environment, such a shortcoming turns into a merit. Naturally, big waves change the sea water in an enclosed sea. However, a man-made offshore structure to protect the waves is used to prevent the change of the seawater, and it causes some pollution problems. Of course, it is very important to keep our lives safe. The authors guess that we will need to consider not only safety but also amenities at the seashore in the very near future.

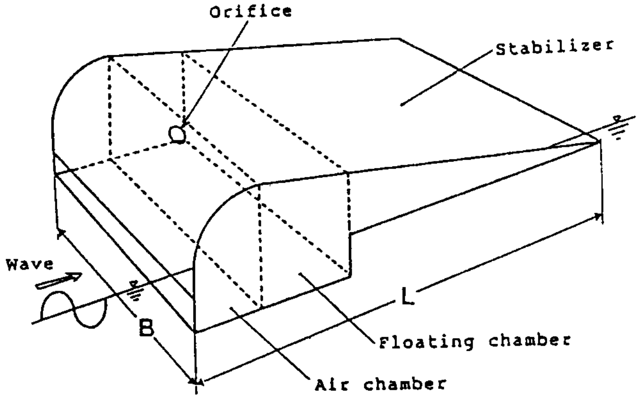

Figure 3. Scheme of the Mighty Whale

Consequently, it is possible to utilize the floating wave power device such as the Mighty Whale as a floating break water. And, it creates a calm sea area behind the device where "aquaculture" or marine sports are possible. Such a device can create conventional space in the ocean near the sea shore.

THE SYSTEM FOR REFRESHMENT OF THE COASTAL ZONE

Structure of the Mighty Whale

The scheme of the shapes of the Mighty Whale is shown in Figure 3. It was designed following results of experiments which were obtained by several tests of KAIMEI, which was a prototype floating OWC wave power device tested in 1978, 1988 and 1985 at the offing of Japan Sea,[4] the shore fixed type wave power generating system which is tested in 1983 near the test site of KAIMEI.[5] This device is considered from three parts: Air chambers, a floating chamber, and a stabilizer slope. Wave energy is converted to air power by OWC of the air chamber, and drives the air turbine. Presently, the Wells turbine is the most promising because its mechanism is not complicated. The stabilizer slope fulfills the function of reducing pitching motion in waves. For marine leisure, because this slope is similar to a natural beach, we can swim in and enjoy it.

Performances of the Mighty Whale

Figure 4 shows the efficiency of conversion of wave power into air power (wave power absorption) versus wave length (λ) divided by length(L) of the device.[6] The data in this figure are obtained by the two dimensional scale model test of 1/100 in regular wave The maximum efficiency of wave power absorpion is about 60% and the width of band of high efficiency is wider than that of the former type of floating wave power device. These results mean the Mighty Whale has excellent performance in wave power absorption.

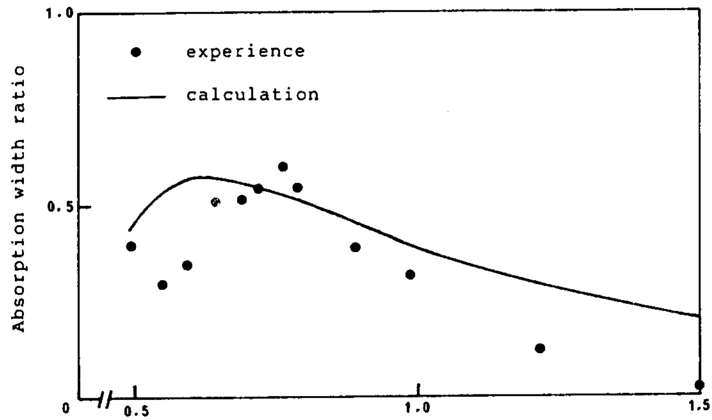

Figure 4. Performance of wave energy absorption in regular waves by the Mighty Whale

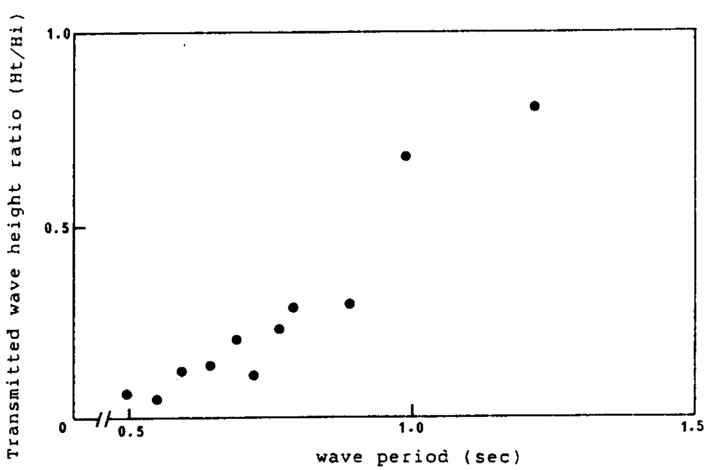

Figure 5. Performance of wave height dissipation by the Mighty Whale

Figure 5 shows the performance of dissipation of incident wave, that is the ratio of transmitted wave height devided by the incident wave height versus λ/L. Since the scale of this model is 1/100, it was 80% within the range of normal sea state at the coast of Japan.

The above results indicate the performance of the Mighty Whale in wave power absorption and dissipation of incident waves is excellent, and better than former types of devices. The reasons for this performance are that the motion of pitching responding to waves is very small due to the stabilizer slope, and the coupling motion between the air chamber and OWC.

The steady drifting force in the waves is also very small, and the minus values were measured sometimes as shown in Figure 6. In this figure, the vertical axis is the drifting force, λ is density of sea water, g is gravitational acceleration, 9 is the breadth of device and Hw is wave height. This figure means the Mighty Whale will be able to go ahead against incident waves sometimes, so that the mooring force is very small in general. Consequently, it was made clear that it will not be difficult to moor the Mighty Whale in waves. This propulsion effect in waves is one of the ways to utilize the wave energy.

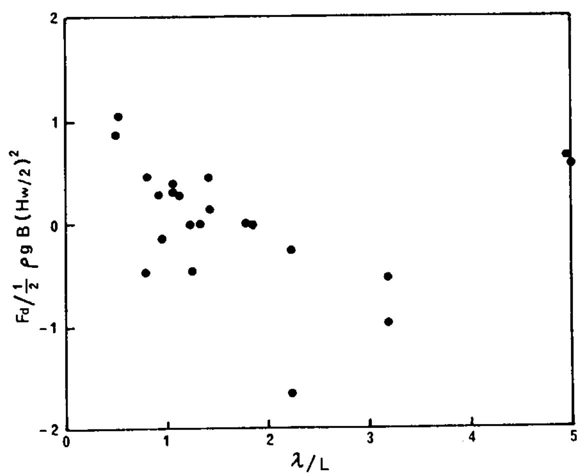

Figure 6. Characteristics of mooring force of the Mighty Whale

Cost of the Mighty Whale

The authors tried to roughly estimate the cost for construction and installation of the Mighty Whale.[7] The total weight of structure of the Mighty Whale of 100m in length will be about 5,700 tons. If we can assume that more than 100 units of the Mighty Whale will be constructed in the future, rough estimation for the construction of such a structure may be about 175,000 yen per one ton of steel weight. So, the cost of this Mighty Whale will be about 1 billion yen per unit.

The cost of the turbine and compressor per chamber will be about 30 million yen. So, the total cost for such equipment for one unit of the Mighty Whale (9 air chambers), including control equipment and other, will be 300 million yen.

The cost for installation including the cost for towing and the mooring chain and anchors may be about 400 million yen per unit. Of course, the cost for such work depends on the site and conditions for installation. So, this cost is estimated from the experience of KAIMEI test and modification of the results for the Mighty Whale.

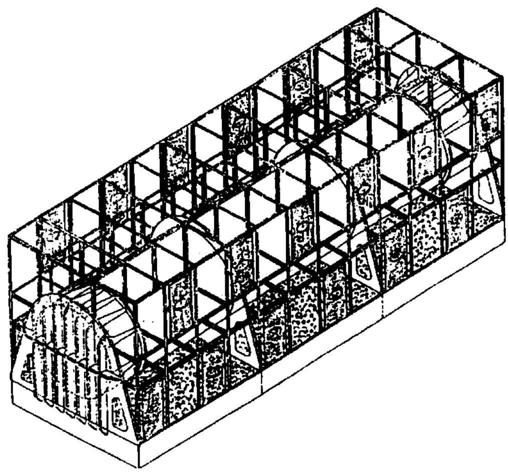

Figure 7. A compressed air tank included into a man-made gathering-place for fish

The Compressed Air System

The compressed air which is generated on the Mighty Whale is transported to the air tank which is installed near the Mighty Whale on the sea bed and balanced with water pressure. Its scheme is shown in Figure 7. It has a valve to control the situation of charge or discharge of compressed air and sea water, which is charged to adjust the pressure in the air tank. The seawater charged in the tank is transported to near the shoreline as same as the compressed air when the air is being charged. The tank has a function for a man-made gathering-place for fish because of the complicated structure around the air tank.

The designed dimension of the air tank is 1.5m in diameter, 20m in length, 60mm in thickness of the wall. The volume in the tank is about 20m^3, and the authors assume it will be installed at the point of 30m in water depth and 1.5km from the shoreline. Furthermore, the subsea pipe to transport the compressed air and sea water was designed as 50mm in diameter.

The cost for construction of the air tank will be about 30 million yen, and 10 million yen for the subsea pipe line. And the cost for installation of the air tank and the pipe lines will be 60 million yen. Consequently, the total cost for the compressed air system will be about 1.8 billion yen.

ABILITY FOR REFRESHMENT OF COASTAL ZONE

The authors predicted the air power converted by the Mighty Whale from wave power, the volume of the compressed air, and effective area for airation near the seashore by one unit of this system.

When we assume that the Mighty Whale will be installed at the site of 2m in the significant wave height and 8 seconds in the significant wave period, the total input wave power for one unit of the Mighty Whale is about 1,400 kW. Since the average efficiency in regular waves of the wave power absorption is about 50%, and the average efficiency of the turbine is about 40%, the input power for 9 units of air chamber to the air compressors is about 280 kW. Consequently, the rated power of the air compressor is about 30 kW.

When the air must be compressed up to 4 kg/cm^2 because the air chamber will be installed on the sea bottom of 30m in water depth, the air compressor of 30kW in rated power can generate the compressed air of about 1400Nm^3/day Since the Mighty Whale is designed in this paper has 9 units of the air chamber, air turbine and compressor, the total volume of the compressed air for the Mighty Whale in a day will be about 13,000Nm^3/day, that is about 0.15Nm^3/sec.

When this compressed air will be utilized for airation at the point of 8m in water depth, it is estimated that the discharge of air of 0.01Nm^3/sec can have effects on the increase of dissolved oxygen in sea water for the area in the coastal zone with a radius of about 50m.

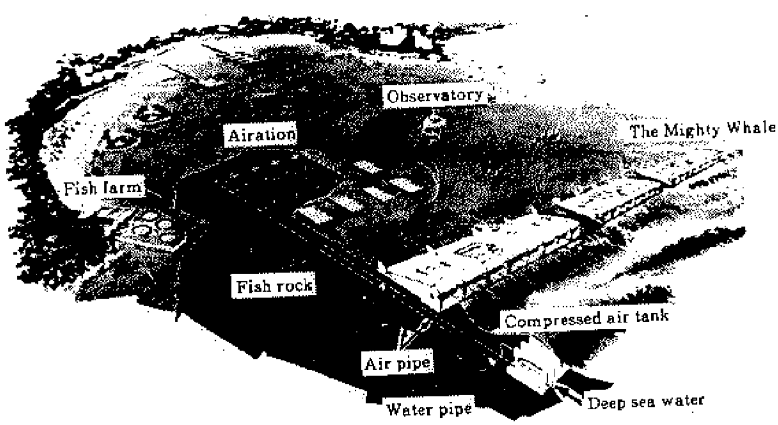

Figure 8. A sheme of the future plan for the utilization of the Mighty Whale for coastal development

Furthermore, when we consider the horizontal diffusion of air bubbles, and the effect of breaking of the layer of sea water by vertical current caused by the movement of bubbles from the sea bottom to the surface, the effective area of airation may widen about double in radius.

Consequently, we can design the distance between each air pipeline on the sea bed for the aeration at about 250m, and this system has 16 nozzles for blow out of the air bubbles. The authors estimate this system can supply air for dissolving oxygen in an area of approximately 1 km.

CONCLUSION

In this paper, the following conclusions were obtained.

1. The possibility and the performance of a system for the refreshment of sea water in the coastal zone utilizing wave power is discussed and authors reach a possible positive solution.

2. It was estimated that the system using the Mighty Whale of 100m in length as a floating OWC type wave power device can refresh seawater by aeration in an area of about 1 km.

3. The cost for construction and installation of this system was estimated to be about 1.8 billion yen for the total system.

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(Edited by P.M. Grifman)

30

Desalination Plants: The Benefit and Impacts of a New Ocean Use in California

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"Water water, everywhere,
And all the boards did shrink;
Water, water, everywhere,
Nor any drop to drink."
The Rime of the Ancient Mariner
Samuel Taylor Coleridge

ABSTRACT

As California moves into a fifth year of drought, the Pacific Ocean is looking better and better as a source of drinking water. While still an extremely expensive process, the desalination of seawater may be the only available alternative for water-parched areas along the Central Coast.

The City of Santa Barbara has recently approved a temporary emergency desalination project, which it hopes to have on line by early 1992 and available for up to 5 years. The project would supply up to 10,000 acre-feet per year (AF= 325,851 gals.), some of which could be made available to other neighboring water purveyors. The plant components include: reverse osmosis (R/O) trains (high pressure pumps, energy recovery turbines, R/O pressure tubes and membrane elements); pump stations and chemical treatment facilities (e.g. chlorine and sulfur dioxide); seawater intake structure and intake pipeline; and brine discharge line.

This paper will address the potential impacts of the brine and chemical discharges on marine organisms. Because the brine discharge from the desalination

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facility will be mixed with effluent from the El Estero Wastewater Treatment Plant, the resultant discharge is expected to result in a range of salinities from 25.9 to 54.6 parts per thousand.

INTRODUCTION

Five years of drought have given Californians something in common with the Ancient Mariner — we're seriously thinking about drinking water from the sea. Faced with a population of 30 million, and growing, and a dwindling supply of fresh water, communities from San Diego to Marin County are making plans to construct expensive shoreside plants to remove the salt from the ocean.

Desalination plants can be used to purify sewage water, brackish groundwater, or seawater. While it is a proven and effective technology that has been widely used in the Middle East and the Caribbean, the desalination of seawater has never been used in the continental United States, because of the high cost compared to other sources of water. In the Cayman Islands in the Caribbean, all of the water comes from desalination. The United States has more than 1,000 small plants that desalinate brackish groundwater. Used primarily for industrial uses, many plants also provide drinking water especially in Florida, where groundwater must be treated before use.[1]

The situation is rapidly changing in California. The first seawater desalination plant in the United States was opened by the U.S. Navy on San Nicolas Island last fall and a second facility, to be operated by Southern California Edison, was scheduled to open on Santa Catalina Island in Spring, 1991. On San Nicolas, the Navy installed a 14,500-gallon-per-day modular unit, similar to those used by the Marines to purify water in the field. A second module of the same size will be installed later this year. The Navy units will produce fresh water at a cost of $1,625 per acre-foot (AF = 325,851 gals.), which is substantantially cheaper than the cost of barging water to the island. The two units will provide all the water needs for the 60 enlisted personnel and 165 civilians who track missiles from the Pacific Missile Test Center at Point Mugu.

A Coastal Commission permit was granted to Southern California Edison and Whitehawk Catalina, Inc. in September, 1989, for a 132,000 gpd reverse osmosis (R/O) plant on Santa Catalina. Speed of construction was a factor in choosing reverse osmosis for service to the Hamilton Cove condominium development. Excess water would go to the Baker Storage Reservoir, providing about one-quarter of the island's total water. The cost of the water is expected to be approximately $1956/AF, which is still cheaper than the $2600/AF residents are paying for water from wells and catchment basins.

WORLDWIDE USE OF DESALINATION

There are more than 7,500 desalination plants worldwide, with over 50% of the plants located in the Middle East.[2] This represents an investment of more than $40 billion. Approximately 25% of the world's installed capacity is in Saudi Arabia alone, where practically all of the plants utilize distillation technology. The largest plant is located at Jubail, Saudi Arabia, producing 128 million-gallons-per-day of potable water. Eight to ten units of seawater pass through these plants to produce one unit of product water.[3] Several of these plants were impacted by the recent oil spills in the Persian Gulf, pointing out the vulnerability of these types of facilities in areas experiencing heavy oil tanker traffic.

Saudi Arabia's state-owned Saline Water Conversion Corp. produces an astounding 500 million gallons (1,500 AF) of desalinated water per day. According to Leon Awerbuch, manager of Bechtel Group's power desalination, and president of the International Desalination Association, Bechtel is competing for $7.5 billion worth of desalination projects in the Middle East alone over the next three years.[4]

Desalination technolgy now produces 3.5 billion gallons of fresh water per day worldwide. That is a fraction of the world's total fresh water use, but is enough to provide 100 gallons a day for 35 million people, more than the current population of California. Some say that desalination could supply all the fresh water that southern California needs, as long as consumers are willing to pay two to ten times current prices.

DESALINATION TECHNOLOGIES

A number of technologies have been developed for desalination, including vapor compression, ion exchange, electrodialysis, distillation, and reverse osmosis. Two of these technologies are being considered for seawater desalination in California: distillation and reverse osmosis. Plants can be built as separate units or in combination with electricity generating plants, where the waste heat is used for the desalination process. One of the existing plants in the state and several proposed projects are for combined plants. In several locations, pilot projects are being proposed to test the relatively new processes before full-scale plants are constructed.

Most of the technology used for desalinating water was developed in the U.S. national laboratories in the 1950s and 1960s. The research was funded primarily by the Atomic Energy Commission, which was looking for uses for what it expected to be cheap energy produced by nuclear power plants, and by the Department of Interior, which foresaw water shortages in the West. While the technology is old and proven, the primary limitation is cost — both the high capital investment for building complicated plants and the operating costs.[5]

Seawater typically contains 35,000 parts per million (35 parts per thousand) of dissolved minerals. Brackish water has up to 10,000 ppm., while water is deemed fit to drink at 500 ppm. In distillation, water is heated until it turns into steam, leaving salt and other contaminants behind. When the steam is condensed, it becomes pure water. In reverse osmosis, the seawater is passed through a thin plastic membrane with pores so small they allow water molecules through but block salts, viruses, bacteria, and other contaminants.

While about 65% of all desalinated water worldwide is produced by distillation virtually all of the U.S. plants are based on reverse osmosis, including those on San Nicolas Island and Santa Catalina Island. The plant proposed in Santa Barbara will also be a reverse osmosis facility. The high costs of reverse osmosis are for the production and maintenance of the sophisticated plastic membranes and for powering the pumps that provide the high pressures necessary to force water through the filters.

DISTILLATION

In the distillation process, seawater is evaporated, separating the water from the dissolved salts, and then it is condensed. Two of the most common distillation technologies are Multistage Flash and Multiple-effect. Multistage flash distillation makes use of the fact that water boils at progressively lower temperatures as it is subjected to progressively lower pressures. The feedwater is heated and the pressure is lowered, causing the water to "flash" into steam. There are a number of stages in series, each of which is operated at a lower pressure.

In multiple-effect distillation, evaporators are operated in series, with the vapor from one series being used to evaporate water in the next one. One of the advantages of distillation plants is that they can have a large capacity, allowing for economies of scale. The method produces very pure product water, ranging from 2 to 50 ppm of dissolved solids. In multiple-effect distillation, the heat transfer procedure is nearly twice as efficient as in conventional distillation, so much less energy is used to produce the same amount of water.

For large quantities of water at a reasonable price, it will be necessary to build distillation plants, probably in conjunction with an electric power plant. In this way, the heat remaining in steam after it has been used to generate electricity could be used to heat seawater for distillation, thereby lowering the cost of energy substantially. R. Philip Hammond, who oversaw development of multistage-flash technology at Los Alamos and Oak Ridge, and who now serves as a consultant to the Metropolitan Water District, believes that the old method will be replaced by multiple-effect distillation (MED), which has been refined at Oak Ridge and by Israel Desalination Engineering, Inc. Currently only about 3.5% of desalinated water in the world is produced by MED.[6]

REVERSE OSMOSIS

Osmosis is a natural phenomenon that causes fresh water to pass through a membrane into salt water. In Reverse Osmosis (R/O), artificial pressure on salt water overcomes this natural osmotic pressure, forcing water molecules from the salty side into the fresh water. Since only water molecules can pass through the membrane, the salt is left behind. The resulting water ranges from 100 to 500 ppm total dissolved solids. The quality of the water produced depends on the pressure, concentration of salts in the feedwater, and the salt permeation constant of the membrane.

Reverse Osmosis has about 50% lower energy requirements than distillation plants, and the feedwater does not have to be heated. Another advantage of R/O plants is that they take up less area than distillation plants. Fouling of membranes is the most serious disadvantage, as the plants must be shut down when they are replaced.

Reverse osmosis can purify brackish water, such as treated wastewater, for approximately $1 per thousand gallons. That compares with $5 per thousand gallons to make seawater potable. For desalting seawater, pumps must operate at pressures of 1,000 pounds per square inch, or more, creating the high cost. Nevertheless, R/O plants often are desirable because they can be constructed in small modules that are rapidly assembled.

The cost and effectiveness of R/O depends on the source of water. For brackish groundwater, which typically has about 10% the salt content of seawater, the pumps operate at the relatively low pressure of 100 to 200 pounds per square inch. The cost can be on the order of $250 per acre-foot (more than enough to supply two families for one year.) By comparison, the cost of imported water in southern California is about $230 per AF.[7]

COSTS AND PRODUCT WATER USE

Cost estimates for purchased water range from $1,600 to $2,400 per AF for R/O plants, and from about $700 to $2,900 per AF for distillation plants. The actual cost of drinking water will be lower than these amounts, because, in most cases, the water from desalination would be blended with less expensive water that contains higher dissolved solids. The other sources of water must be piped on site to be mixed with the desalination product because the pure desalinized water would corrode pipes.[8]

Product water may be used for irrigation, industrial uses, power plant process water, or drinking water. Some project proposals call for use at the desalination site only, while others intend to sell the water produced. Drinking water in southern California is presently purchased for about $280/AF, although the least expensive new supplies would cost $600-700/AF. Alternatives, such as Santa Barbara tying into the State Water Project, or expanding reservoirs, could cost up to $980/AF. With desalinated seawater being mixed into the grid supplying water from conventional sources, consumers can expect their water bills to increase about 25 percent.

At nearly $2,000/AF, desalinated water will be much more expensive than water from conventional sources. However, as drought conditions and long-term water supply conditions worsen, desalination becomes a more viable option. The promise of desalination as a future supply of water, especially along the Central Coast, has raised the controversy of coastal development and growth inducement. This paper will not address these issues, but will focus on the impacts to the marine environment from the construction and operation of proposed plants.

EXISTING PROJECTS

In addition to the U.S. Navy's two R/O units on San Nicolas Island and the Santa Catalina plant, there are three other desalination facilities that have been operating in California: Chevron's Gaviota Oil Processing Plant, the Diablo Canyon Power Plant, and the Moss Landing Power Plant. Additionally, the Orange County Water District has operated, since 1977, a 15-million gpd R/O plant at Fountain Valley. The plant cleanses treated sewer water to drinking water standards and pumps it into the ground to repell saltwater intrusion.[9]

Gaviota. The R/O desalination plant began operation in 1987 and was designed to last 25 years. Designed to produce 285 gals/min of water, the plant actually produces about 60 gal/min for onsite use. The plant produces several grades of water, with the least pure about 500 ppm, and the most pure about 50 ppm salts. The cost to produce the water is about $4,000/AF. Chevron obtained Final Development Plan approval from Santa Barbara County in 1985, with a condition that required onsite seawater desalination to provide 100% of the Gaviota facility's freshwater requirements.

Diablo Canyon. A Multi-Stage Flash distillation plant was built in 1985 and is still operating, although it was only designed to last three years. PG&E is planning to refurbish the plant or begin new construction sometime in 1991. Product water, usually under 200 ppm, is used on site in the nuclear power plant, which requires nearly pure water for steam. The plant uses energy recovery from the power plant, but product water still costs about $1,500/AF.

Moss Landing. Exhaust steam from the PG&E power plant is used in a Mechanical Vapor Compression Evaporator desalination plant. The plant is rated at 216,000 gpd, with the 1 ppm product used in the power plant turbines.

PROPOSALS

There are some one dozen desalination plants, in six central and southern California counties, and Baja California, being planned for the near future. These proposals will be discussed briefly, starting with Marin County in the north, and running south to Mexico.

Marin County. The Marin Municipal Water District recently completed a three-month desalination pilot study at the Marin Rod and Gun Club near the Richmond-San Rafael Bridge. The pilot plant produced about 2,500 gal/day of drinking water. Placed before the voters in November, 1991, the $55-65 million R/O plant would produce purified San Francisco Bay water for $2,400/AF. The pilot study looked at different filter designs, which is critical if Marin wants the new plant to meet the 100 ppm purity of existing supplies.[10]

Monterey County. On the Monterey Peninsula, the water management district joined forces with the Marina water agency and Pacific Gas & Electric Co. to explore the possibilities of desalting seawater as a way to supplement the groundwater being pumped by wells. They plan to build a $20 million plant to produce 2,000 AF/year, with an intended operation date of 1995. The plant will be built in Monterey, Marina, or Moss Landing. The Monterey Bay Aquarium and proponents of Monterra Ranch, a housing subdivision planned alongside the Monterey-Salinas Highway, have applied for the first county permits to build their own desalination plants. The Sterling Hotel/Conference Center, proposed for Sand City, would fulfill some of its freshwater needs with a 18,000 gpd R/O plant.[11]

San Luis Obispo County. The City of San Luis Obispo is studying R/O or a vapor compression distillation plant to be located on Morro Bay. If approved, the 3,000 AF/year plant would be built within two years. The City of Morro Bay is considering an emergency short-term plant that would be built if the current drought continues. It would have a capacity of 1 to 1.2 million god and run for six to nine months in late 1991. An existing R/O plant, built by the Department of Water Resources, is proposed to be transported to the Hearst Castle Visitor Center, for drinking water. The capacity of the portable plant is 40,000 gpd, but it is planned to operate only 16 hours/day, for an output of 26,000 gpd.

City of Santa Barbara. Santa Barbara, the hardest hit area in the state by the drought, has contracted for construction of a $25 million R/O desalination plant, expected to produce one-third of the city's requirements by early 1992. Ionics, Inc., a publicly traded company headquartered in Watertown, Mass., would build, own, and operate the plant, and supply water to the city for $1,953 per AF. The plant, housed in temporary trailers, is considered an emergency drought measure, but its use could be extended. Speed is especially important to Santa Barbara, where water resources have literally evaporated. The permit process should be completed by this summer, with construction expected to be finished in 15 months.

Los Angeles. The Metropolitan Water District, which supplies water to much of southern California, expects to have a 5-million gpd pilot desalination plant on line within three to four years and to begin construction of a full-scale 100-million gpd plant in San Diego a year later. The multiple-effect distillation plant most likely would be added to San Diego Gas & Electric's Encina or South Bay generating facilities when obsolete boilers are converted to gas turbines in the next few years. The cost of water from the pilot plant is expected to be about $1,000/AF, but the cost of water from the full-sized facility could be less than $500/AF.

San Diego County. The San Diego County Water Authority is soliciting proposals for combining desalination projects with a new or expanded power plant for SDG&E. The are considering both R/O and distillation, to produce up to 50,000 AF/year.

Mexico. Plans for a large seawater desalination plant, including a power plant, have been drawn for an unspecified site near Tijuana, 140 miles south of Los

Angeles. The plant would cost up to $2 billion, with each of six principals in the project contributing $100,000 for a six-month study to examine the feasibility of producing 100 million gallons of potable water daily. Waste heat from the natural gas-fired power plant would be used to distill the seawater.[12]

IMPACTS

In addition to normal construction impacts, such as noise, visual, and public access, and seafloor disturbance, turbidity and damage to kelp beds during pipeline construction, there are several potential impacts to the marine environment from the operation of a desalination plant. The following discussion will not address air emission impacts from the associated energy generation facilities. Discussion will be limited to chemicals in the discharge water from pre-treatment of the feedwater, effluents from pipeline flushing and R/O membrane cleaning solutions, and the disposal of concentrated brines.

According to the Draft Environmental Impact Report (EIR) for the City of Santa Barbara's Temporary Emergency Desalination Project,[13] there are several chemicals which will be used in the desalination process which could pose a hazard to the environment. These include: chlorine, sulfur dioxide, sodium hydroxide, ferric chloride, carbon dioxide, antiscalent, zinc orthophosphate, and polyelectrolyte.

The desalination process will use approximately 880 pounds of chlorine per day for the pre-treatment of feedwater and 872 pounds of sulfur dioxide to remove the chlorine prior to R/O desalination. Approximately 3,000 pounds per day of caustic soda (sodium hydroxide) will be required for pH adjustment of the treated water and 3,300 pounds of ferric chloride will be used as a filter aid in feedwater pre-treatment. Approximately 2,480 pounds of carbon dioxide will be used daily for pH adjustment of the R/O feedwater.

While the following sections will address discharges in connection with R/O plant operations, such as the proposed Santa Barbara facility, there are additional impacts, such as fish impingement and entrainment at seawater intake lines, and increased water temperatures for discharges from distillation plant operations, which must also be recognized.

Pre-treatment of feedwater. Seawater must be free of sand and other particulate matter before it can be introduced into the R/O membrane desalting units. This would be accomplished in a system of primary and secondary media filter units that maintain a chlorinated environment to prevent bacterial or other growth in the filtration units. Chlorine will be added to the seawater at the onshore intake pumping station along with carbon dioxide for pH reduction and ferric chloride for coagulation of suspended solids. Any residual chlorine present after the filtration retreatment will be removed by the addition of sulfur dioxide or sodium bisulfite prior to R/O desalination.

Filter backwashing and membrane cleaning. The primary and secondary filters will require periodic cleaning or "backwashing" to clear the accumulation of sand

and solids which the filter will remove from the seawater. Primary filters will be backwashed daily, secondary filters will require backwashing about every three days.

The R/O membranes will require periodic cleaning to remove organic and inorganic foulants and scale in order to maintain satisfactory membrane efficiency and throughput. Typically, alkaline cleaners are used to remove organic fouling, including biological matter, whereas acid cleaners are used to remove calcium carbonate scale and other inorganic precipitates including iron.

Brine disposal. According to the EIR the residual brine solution would be piped to an existing sewer outfall, diluted with treated wastewater from the Wastewater Treatment Plant, and then discharged into the ocean. Up to 13.3 million gallons per day of concentrated seawater brine, plus backwash, will be discharged to the ocean by way of the City's existing outfall for the El Estero Wastewater Treatment Plant. Assuming 45 percent recovery for the 10,000 AF/year project, the brine salinity will approximately 1.8 times the seawater salinity.

In addition to the concentrated salts, the R/O brine will also contain antiscalent, which is injected into the filtered seawater for scale control, and all particles, suspended matter, coagulent, polyelectrolyte, and organics that are not removed by the primary and secondary media and cartridge filters.

One ecological consequence of the attendant changes in salinity is that marine organisms with broad salinity tolerances are expected to predominate in the immediate vicinity of the discharge. An additional concern voiced by some marine biologists is the possiblity that certain trace elements, depending on the pH and oceanographic conditions, will concentrate in the surface microlayer above the plume and prove to be toxic to plankton, fish eggs, and larvae.[14] There is also the possibility that concentrations of these chemicals could be wind or current driven into the intertidal zone, causing problems for other organisms.

CONCLUSION

On the surface, it appears that the benefits of seawater desalination far outweigh the impacts to the marine environment. However, because of the array of chemicals used in the reverse osmosis process, and because of the many uncertainties surrounding the behavior of the concentrated brine discharge in the ocean, it is critical that any permit approvals for desalination facilities include stringent monitoring conditions. Levels of trace metals should be measured in the surface microlayer above the discharge plume and pH should be monitored constantly throughout the system. Marine scientists should conduct research on the interactions of various chemical elements, specifically as they relate to biological processes. For example, if zinc is used as a chemical treatment in the R/O process, and is discharged into marine waters, what impact would that have on the zinc/silica balance for diatoms? These, and other questions, must be answered before California turns in earnest to the sea as a source of drinking water.

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Data from the Coastal Zone: What is Planned by the National Data Buoy Center

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Stennis Space Center, Mississippi

ABSTRACT

The National Data Buoy Center (NDBC), an agency of the National Weather Service, collects meteorological and oceanographic data from a network of 60 moored buoys, 50 Coastal-Marine Automated Network (C-MAN) stations, and a myriad of drifting buoys. These platforms are the major means through which NDBC accomplishes its mission objectives. While a wide variety of data are now collected, there are always improvements to be made and additional data to be collected. This paper will address the data now being collected and the availability of that data, what developments are in process and the improvements they will produce, and what is still needed and appears realistically achievable in the future.

Data now being collected include winds, waves, air and sea temperatures, atmospheric pressure, humidity, solar radiation, and rainfall. Much of NDBC's current efforts are directed at improving those measurements through more cost-effective approaches, such as the use of magnetometers to acquire directional wave data, or by adding new instruments, like acoustic Doppler current profilers, to our platforms. In the future, the geographic flexibility of the systems will be broadened through use of additional satellites, acoustic links will be used to acquire high quality subsurface data, and lower cost methods to acquire currents will be developed.

NDBC has always collected and disseminated quality data. Improvements in sensors and techniques have produced a trend toward reduced costs for data collected. New initiatives will continue that trend, making data collection activities even more common in our coastal waters and harbors.

International Perspectives on Coastal Ocean Space Utilization
Phyllis M. Grifman and James A. Fawcett, Editors

INTRODUCTION

The National Data Buoy Center (NDBC), located at the Stennis Space Center (SSC) on the Mississippi Gulf Coast, is an element of the National Weather Service (NWS), National Oceanic and Atmospheric Administration (NOAA), Department of Commerce. It is an organization of 173 government and contractor employees, including active members of the U.S. Coast Guard (USCG), whose mission objectives are: (a) operate a network of environmental monitoring platforms in the deep ocean and coastal regions that provide accurate and reliable data for NWS and other users; (b) provide ocean engineering operations supporting NOAA's measurement programs; (c) serve as a center for environmental data buoy and associated automated meteorological monitoring system technology by conducting development, test, and evaluation of new, automated, marine-monitoring systems; (d) support non-NOAA environmental monitoring applications for those situations where NOAA deems it to be in NOAA's best interests; and (e) provide systems engineering for the development and evaluation of automated observing systems.[1]

These mission objectives are satisfied as a result of funding from the NWS, Minerals Management Service (MMS), the Army Corps of Engineers (COE), and other sponsors. At-sea operations are conducted with the considerable support of the USCG.

To accomplish the NDBC mission, these major program categories are addressed:

- Warning and Forecast Services
- Climate and Related Services
- Technology Development and Demonstration Services.

Warning and Forecast Services

Warning and Forecast Services constitute NDBC's primary program category and makes up a major portion of its programs. The programs supporting the Warning and Forecast Services are: provide operational marine and coastal meteorological and oceanographic observations in real time via satellite links to the NWS Telecommunications Gateway (NWSTG), to the NWS's National Meteorological Center (NMC) for analysis, to regional and local NWS offices for use in developing forecasts and warnings, to other users via the NWS Family of Services, and to the international community through the Global Telecommunications System (GTS). In support of these systems, NDBC provides for archival of quality controlled data for the development and refinement of climate modelling sytems.

Climate and Related Services

The Climate and Related Services program consist predominantly of reimbursable activities that support the Office of Oceanic and Atmospheric Research (OAR). A lesser level of climate and research effort is also conducted in support of Department of Defense (DOD) programs and projects. A major, ongoing activity for OAR and the National Ocean Service (NOS) is the Climate and Atmospheric Research Tropical Ocean and Global Atmosphere (TOGA) project. The TOGA project is a 10-year project, which began in 1985, with investigative activity centered on the Southern Oceans.

Technology Development and Demonstration Services

The third program category, Technology Development and Demonstration Services, includes both base-funded technology development projects in support of ongoing NDBC programs, and reimbursable, joint-agency demonstration projects whose systems are in the transition phase between research and development and becoming fully operational. These research/developmental systems also provide quality controlled data used as ground truth for remote sensing systems.

Technology development applications are directed at the assessment and introduction of new sensors, payloads, and platforms to meet either customer requirements for new observations or to improve the efficiency/capability of existing NDBC systems. NDBC's role in demonstration projects is to provide the mechanism for transition of developmental observation systems technology from the research arena through a demonstration program to the point where operational systems can be implemented. This role encompasses systems engineering and programmatic support of the demonstration program, and typically does not extend into either the research or operational aspects.

Operating Philosophy

As mentioned, NDBC is a NOAA organization that functions as an interagency activity, with the USCG as an integral part of the NDBC team. NDBC maintains the philosophy of delivering high quality environmental data in real time from data-sparse areas to the NWS and to other agencies. This is accomplished by using only operational equipment that has been thoroughly and successfully tested in the marine environment. Comprehensive maintenance, calibration, reliability, and data quality control programs are used to ensure these data standards are maintained.[1]

NDBC has a policy of contracting out that extends to network operation and technical support by an in-house support contractor. The Data Buoy Support Contractor (DBSC) provides support to NDBC in the areas of engineering, operations, quality assurance, and data processing and dissemination. Having a dedicated support contractor adds flexibility to the NDBC program and allows timely adjustments to changing program needs.

MAJOR PROGRAMS

The following are the major programs being pursued at the National Data Buoy Center:

- Coastal-Marine Automated Network
- Drifting Buoy Program
- Moored Buoy Program
- Waves Program
- Upper-Air Wind Profiler System.

Coastal-Marine Automated Network

In response to the need for automation of coastal observations lost by the USCG's automation of lighthouses and light ships, the C-MAN program was established in 1981 by the NWS.

NDBC was called upon to provide automated meteorological data collection systems to gather data that had been manually collected. The existing network of C-MAN stations (Figure 1) includes USCG lightstations on offshore platforms, USCG lighthouses on offshore islands and headlands, fixed stations on beaches and public fishing piers, and USCG Large Navigational Buoys (LNB's) and Exposed Location Buoys (ELB's). These are all platforms of opportunity owned by other activities. Additionally, in a joint effort called Meteorological and Oceanographic Measurement System (MOMS), a joint oil industry consortium sponsored NDBC to

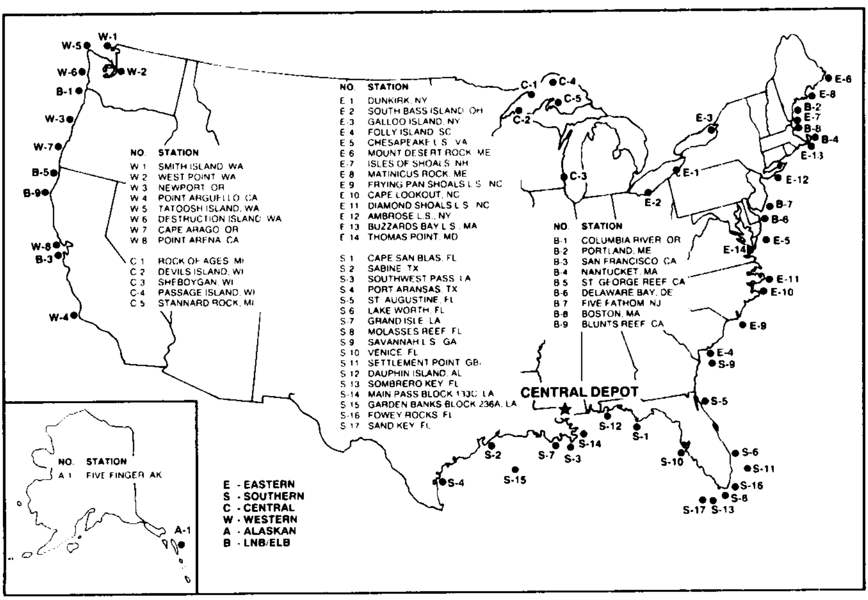


Figure 1. C-MAN sites

install C-MAN stations on Chevron's offshore oil platforms (Main Pass 133C and Garden Banks 236A in the Gulf of Mexico). Also, during the latter part of 1988, the U.S. Navy sponsored a C-MAN site on Faraulep Island in the Pacific, south of the island of Guam. This site supports the typhoon warning efforts of that region. An additional 20 WESTPAC stations are planned. Installations have been made at Ujae, Eniwetok, Pagan, Kusaie, and Mili.

NDBC supports some scientific expirements and short-term monitoring projects with C-MAN stations. The Genesis of Atlantic Lows Experiment (GALE) and Subtropical Atlantic Circulation Study (STACS) programs are examples where new stations were installed or additional parameters were added to existing sites. NDBC also receives and provides quality control of weather observations reported from automatic stations on Shell platforms in the Gulf of Mexico. Figures 2 through 4 show typical C-MAN sites.

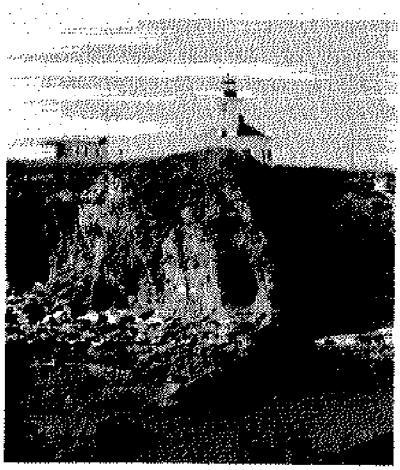


Figure 2. Cape Arago Light Station, OR

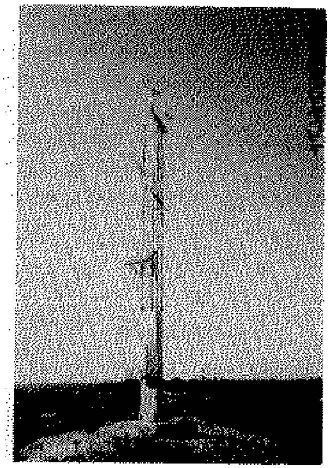


Figure 3. Cape Lookout, NC

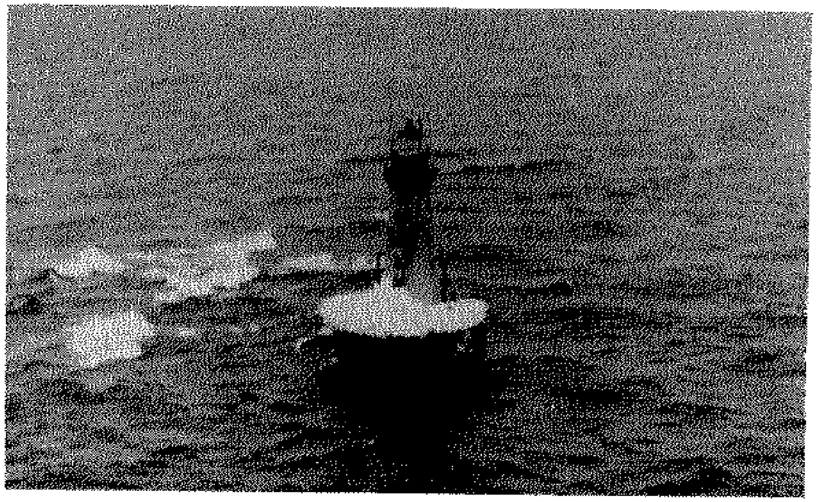


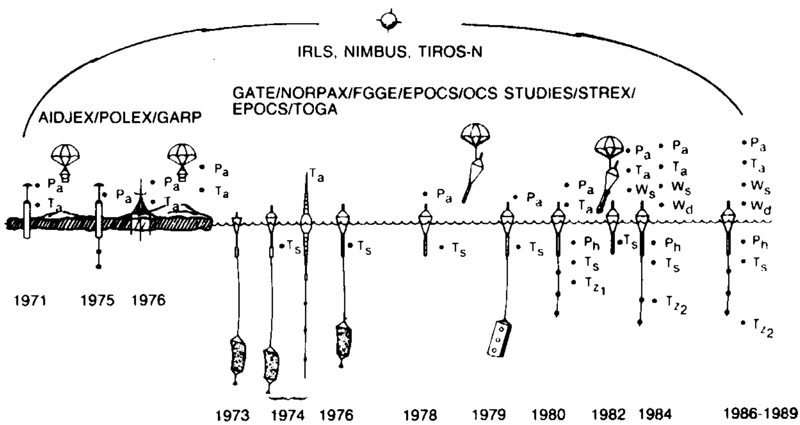
Figure 4. Stannard Rock, MI

The initial electronics payload developed for the C-MAN program was the Data Acquisition Control and Telemetry (CACT) system. The DACT is an automated, self-timed system that collects, analyzes, and telemeters the data. Certain C-MAN sites can be accessed by telephone landlines to obtain the latest observations, which are updated every 15 minutes. The basic DACT measures wind speed and direction, air temperature, water temperature, and barometric pressure. The DACT system has spare channels for expansion, and some sites measure other parameters such as waves, tides, humidity, and precipitation.

NDBC has developed an improved, more cost-effective payload, the VEEP (Value Engineered Environmental Payload), which will be replacing many of the DACT's for C-MAN and coastal buoy applications in the near future.[2]

Drifting Buoy Program

During the last two decades, a series of polar-orbiting satellites were launched that had the capability to telemeter surface platform data and position location data. This capability gave impetus to the development of relatively low-cost oceanographic and meteorological drifting buoy data collection platforms (DCP) to support a diverse range of weather and climate observational programs. The Drifting Buoy program is, for the most part, a cost-reimbursable program for NDBC. Figure 5 depicts the development of drifting buoy technology since 1971.



T_{z_1} —HARD WIRED LINE

T_{z_2} —MULTIPLEX LINE, SINGLE PAIR OF WIRES FOR UNLIMITED NUMBER OF SENSORS

Figure 5. Drifting buoy technology development

The First GARP Global Experiment (FGGE) demonstrated the scientific value of drifting buoys and their importance for real-time weather forecasting. Additional capabilities were developed for drifting buoys (e.g., wind speed and direction and waves measurement capabilities). "Drifters" have proven their capability for producing valid measurements of wind speed in hurricanes, subsurface temperature, and inferred ocean surface current direction and speed. Wind direction buoys also have proven successful. The wave-measuring capability is still under development. As mentioned above, drifting buoys can be deployed from almost any surface vessel, are air-deployable, and they are relatively inexpensive and expendable. It is normally not cost-effective to plan on recovering these buoys.

Drifting buoys play an important role in the TOGA research program, which began on January 1, 1984. TOGA is a 10-year study of regional climatic variations and of the El Niño/Southern Oscillation (ENSO). One of the United States' major contributions is to maintain a network of approximately 50 drifting buoys in the Southern Hemisphere. The buoys provide invaluable information on currents, winds, and temperatures in ENSO regions. Figure 6 depicts the location of drifting buoys as of October 26, 1989.

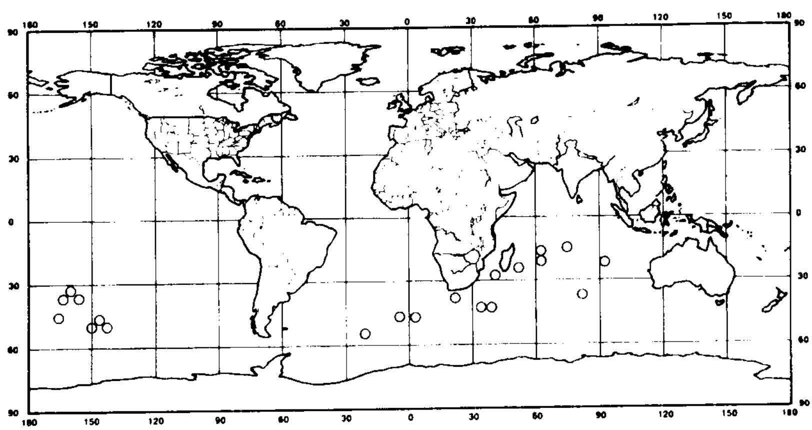


Figure 6. Drifting buoy positions October 26, 1989, 00Z

Drifters also provide short notice backup to other measurement systems. When an imagery outage of the GOES system caused a lack of satellite coverage in the western Atlantic and the Hawaiian areas, drifters were deployed in these areas until the situation was alleviated. Six drifting buoys were air-deployed by Air Force C141 aircraft in August 1985 — four buoys in low-latitude western Atlantic locations and two drifters southeast of Hawaii. These buoys provided valuable information on tropical weather systems, and the newly developed wind direction measurement capability was verified on three of the buoys.[1]

Moored Buoy Program

The objective of the NDBC moored data buoy network is to monitor and relay data on environmental conditions from data-sparse marine areas to forecasters who issue warnings and to other users who conduct environmental studies. The principal users are the operational forecasters of the NWS and certain other government and non-government forecasting organizations who use the data for oceanic, coastal, or Great Lakes predictions. The data are also important at international meteorological centers.

The moored buoy network is presented in Figure 7. NDBC's basic buoy operations consist of core stations selected to support NWS data requirements. The network is augmented by buoys that support various government agencies (e.g., COE and MMS). Many of these buoys are located offshore at distances greater than 150 km, including several around Hawaii and in the Gulf of Alaska. Data from these offshore buoys are vital for detecting the intensity and movement of storms. These buoys also provide important observations for analysis of pressure and wind fields for numerical weather prediction.

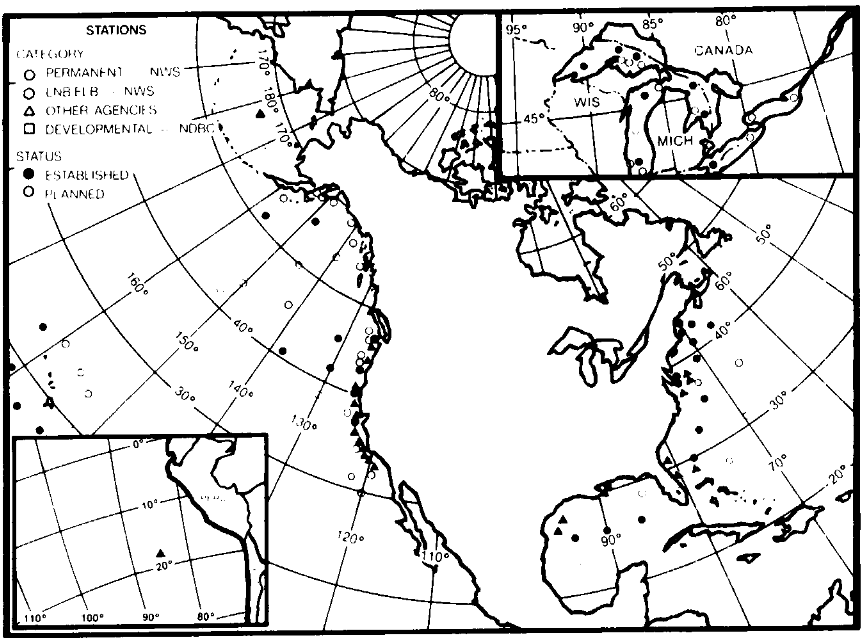
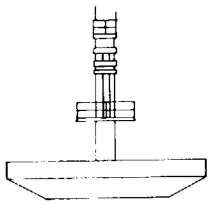


Figure 7. NDBC buoy locations

Moored data buoys located in nearshore areas and the Great Lakes include buoys that support MMS studies off the California coast and in the Gulf of Mexico; buoys off southern California funded in the past by the U.S. Navy, NOS, and MMS;

and directional wave measurement buoys, in a variety of locations, that are funded partly by the U.S. Army Corps of Engineers.

The buoy hull types that comprise the moored buoy network are the 10-meter and 12-meter large discus; the 6-meter, boat-shaped Navy Oceanographic and Meteorological Automatic Device (NOMAD); the 3-meter discus, and a 2.3-meter Coastal Buoy (under development) (Figure 8).

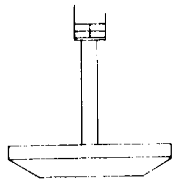


12-METER DISCUS

1. EEP (12DO3 - 12DO8)

a. HULL WEIGHT	104,000 LB
b. POWER SYSTEM	4,000 LB
c. PAYLOAD	400 LB
d. BALLAST	81,600 LB
e. DEPLOYED	190,000 LB
f. VCG	4.3 FT

2. ONR (12DO1, 12DO2)



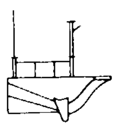
10-METER DISCUS

1. EEP (10DO1 - 10DO6)

a. HULL WEIGHT	60,000 LB
b. POWER SYSTEM	4,000 LB
c. PAYLOAD	400 LB
d. BALLAST	49,600 LB
e. DEPLOYED	114,000 LB
f. VCG	3.6 FT

2. VE (10DO7 - 10D11)

a. HULL WEIGHT	57,000 LB
b. POWER SYSTEM	4,000 LB
c. PAYLOAD	400 LB
d. BALLAST	52,600 LB
e. DEPLOYED	114,000 LB
f. VCG	3.8 FT



6-METER NOMAD

1. USN (6NO1 - 6N15)

a. HULL WEIGHT	10,000 LB
b. POWER SYSTEM	3,000 LB
c. PAYLOAD	350 LB
d. BALLAST	5,900 LB
e. DEPLOYED	19,250 LB
f. VCG	4.74 FT

2. VE (6N16 -6N30)

a. HULL WEIGHT	9,400 LB
b. POWER SYSTEM	3,000 LB
c. PAYLOAD	350 LB
d. BALLAST	6,500 LB
e. DEPLOYED	19,250 LB
f. VCG	4.24 FT

3-METER DISCUS

1. (3DO1)

a. HULL WEIGHT	2,590 LB
b. POWER SYSTEM	610 LB
c. PAYLOAD	100 LB
d. BALLAST	0 LB
e. DEPLOYED	3,300 LB
f. VCG	2.5 FT

2. (3DO2 - 3D19)

a. HULL WEIGHT	2,600 LB
b. POWER SYSTEM	660 LB
c. PAYLOAD	210 LB
d. BALLAST	0 LB
e. DEPLOYED	3,470 LB
f. VCG	2.4 FT

2.3-METER COASTAL

1. (2.3DO1)

a. HULL WEIGHT	1180 LB
b. POWER SYSTEM	330 LB
c. PAYLOAD	240 LB
d. BALLAST	0 LB
e. DEPLOYED	1,750 LB
f. VCG	2 FT

Figure 8. Moored buoy hull characteristics

The 12-meter-diameter discus buoys, historically deployed in severe environmental areas, have been augmented and are gradually being replaced by the more cost-effective 6-meter, boat-shaped NOMAD buoy, which has proven its ability to withstand severe conditions and still acquire accurate and reliable data. An example of the NOMAD's extreme environment operating ability is that of recording a 15.1-meter significant wave height in January 1990 in the North Pacific Ocean.

To reduce buoy deployment costs, NDBC developed the 3-meter-diameter discus buoy, which was initially designed by Woods Hole Oceanographic Institution. This buoy uses the same type of electronics payload package and sensors as the C-MAN sites and other buoys.

Various test programs conducted by NDBC have proven the 3-meter buoy to be very reliable. It has been deployed in several coastal locations, off the west coast of South America, in the Great Lakes, and off the coast of the United States. Additionally, NDBC deployed a 3-meter buoy for testing in the Alenuihaha Channel, Hawaii, which has since been recovered. The plans are to gradually replace the nearshore NOMAD's with 3-meter buoys. The 3-meter also is the primary buoy used for directional wave measurements.

To provide a low-cost accurate wave measurement syystem to a number of coastal sites, a small coastal buoy development effort was started. This buoy will be small and inexpensive and will provide a limited data collection platform that can relay data reliably to a nearby coastal station over a short-range radio link. The smaller size will result in less costly deployments in the more benign coastal and estuarine areas.[2]

Waves Program

The objective of the NDBC Waves program is to develop and demonstrate systems capable of acquiring and reporting high-accuracy, ocean-surface wave data from buoys and other marine platforms. Strong emphasis is placed on assuring that accurate wave data are provided to a variety of users through both real-time reporting and archiving. The wave data have been used by NWS, NOS, COE, MMS, USN, USCG, and the U.S. Maritime Administration, as well as a variety of other users.

The NDBC wave-measuring systems include nondirectional (both floating and fixed platform), buoy directional, fixed platform directional, and wave data management and distributive systems.

The buoy nondirectional, wave-measuring systems use an accelerometer fixed vertically in the buoy hull and an onboard data processor. The processed data are transmitted to shore where spectra, wave height, and wave period are computed.

The directional wave-measuring systems for buoys use a more sophisticated onboard processing system. Using vertically stabilized sensors to measure buoy hull heave, pitch, and roll, several parameters are computed, including directional data, displacement spectra, wave height, and period. A need is now foreseen by NDBC to measure wave data in the vicinity of C-MAN fixed stations. Operational systems for fixed platform directional wave data may require site-specific designs and local communications links to recover valid wave data.

Wave data management and distributive systems activities include all calibration and data quality assurance systems and real-time and archival data distribution systems at SSC, NWSTG, National Oceanographic Data Center (NCDC), and elsewhere where NDBC data may be processed or used.[1]

Upper-Air Wind Profiler System

Over a decade ago, NOAA's Aeronomy Laboratory constructed its first wind profiler at Sunset, Colorado. In 1980, NOAA established a Wind Profiler program at its Environmental Research laboratory (ERL) to further explore the feasibility of an upper-air monitoring system. Results of this study demonstrated the ability of pulsed Doppler radar signals, electronically steered to the east and north of a vertical beam, to accurately measure wind speed and direction at discrete altitudes up through the troposphere.

Again, as a result of NDBC's established ability to develop procurement-ready specifications, NDBC was asked to suupport a demonstration program. A Request for Proposals (RFP) was issued for prototype and production wind profiler systems on August 27, 1985. In June 1986, a competitive contract was awarded to the Sperry Corporation (now UNISYS).

The first prototype system was installed in Platteville, Colorado, in August 1988, and the second prototype was installed at the UNISYS facility in Bloomfield, Connecticut, in September 1988. Fifteen of the 30 profiler demonstration systems are presently installed, including one in Homer, Alaska.

DATA

Accurate and reliable environmental data are of utmost importance to the ongoing success of the NDBC mission. As of September 1990, the number of data messages delivered annually in real-time (Table 1) exceeded one million. Both automated and manual quality control audits of environmental data are performed to ensure that the quality and reliability of these data conform to prescribed commitments made to the user community.[1]

Table 1

NDBC Data Products Delivered in Real Time

	DATA MESSAGES			
	METEOROLOGICAL			
FY	BUOY	C-MAN	TOTAL	OCEANOGRAPHIC
1978	40,424		40,424	26,152
1979	111,086		111,086	39,086
1980	141,762		141,762	86,789
1981	192,098		192,098	155,248
1982	259,273		259,273	222,048
1983	297,599	21,370	318,970	269,571
1984	288,739	143,505	432,245	253,164
1985	324,869	282,362	607,231	275,896
1986	302,349	292,826	595,175	283,503
1987	329,325	308,901	638,226	316,184
1988	352,796	315,378	668,174	329,753
1989	363,808	346,612	710,420	362,554
1990	373,869	379,610	753,479	387,121

All data and status parameters available are continually monitored to ensure the timely detection, correction, or removal from real-time dissemination of invalid data products. The data quality audits include data comparison between redundant sensors and different data types, and graphic hardware and software.

The DBSC provides for operation of data communications among the nodes of the NDBC data network, and maintains data processing and control of files at the National Environmental Satellite, Data, and Information Service (NESDIS) and the NWSTG. Network ccommunication evaluation and status reports are produced daily. NDBC's standard data products and special reports are delivered per published schedules. Information storage for data products, such as tabulations and magnetic media, are maintained.

Data that are nonrepresentative or incorrect are restricted from release to users. The technical analysis of the data includes daily monitoring of the NDBC-processed data to assure the validity of all data being distributed to users. Editing of the data to remove errors prior to archival at NCDC and NODC is also a responsibility. All data collected by NDBC are availble from these centers. Figures 9 and 10 depict the data flow for NDBC stations.[1]

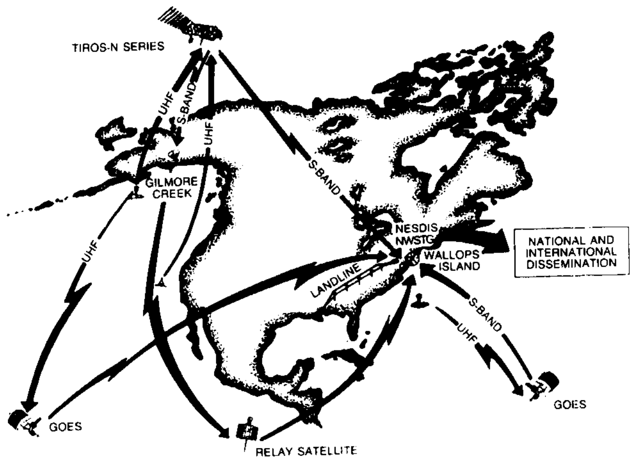


Figure 9. Data acquisition from environmental buoys

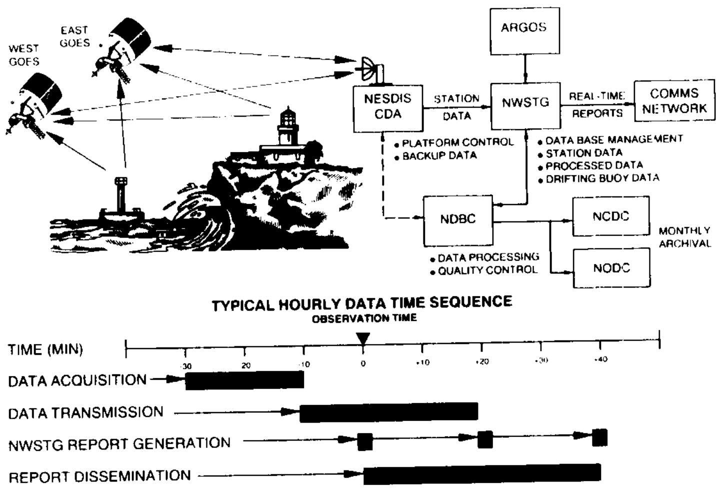


Figure 10. Data flow

THE FUTURE

Plans to improve the data collection networks are underway at NDBC. They range from more efficient or less expensive means to collect the kinds of data now routinely collected to the colleciton of new data from existing platforms. What follows is a brief discussion of some of these innovations.

Magnetometer-Only System

The measurement of directional wave spectra using an ordinary slope-following buoy requires the measurement of hull pitch and roll. Although accurate pitch and roll measurements can be made by active sensors based on gyroscopic principles, the energy consumption of such sensors is significant, their lifetimes, in operating hours, are limited, and they are costly. These disadvantages have led to the use of passive sensors aboard buoys that need to operate unattended at remote stations for periods measured in years.

Although a number of vendors purport to offer sensors that measure pitch and roll with passive sensors that are small and inexpensive, usually one finds that the measurements are only valid for static conditions. To our knowledge, no small, inexpensive sensors are available on the market that can provide accurate measurements of pitch and roll in the presence of horizontal acceleration.

The lack of such a sensor largely accounts for the fact that almost all (if not all) pitch-roll directional wave measuring buoys in the world make use of one of the "HIPPY" heave, pitch, roll sensors. Datawell, in Holland, has been building these sensors for many years. They are accurate, consume little power, and are quite reliable when handled properly. On the other hand, they are quite heavy and bulky, placing a lower limit on the size of the buoy aboard which they may be used. In recent years, the cost of the sensors has also represented a substantial percentage of the total cost of a buoy.

For several years, NDBC has pursued new, low-cost methods for measuring pitch and roll aboard buoys measuring directional wave spectra. We are now enthusiastic about a method that, for lack of a better name, is called the magnetometer-only (MO) method for measuring directional wave spectra. It is so called because our standard buoy for measuring directional wave spectra uses a HIPPY 40 and a triaxial magnetometer to measure pitch and roll, and the MO system requires only the magnetometer (and a fixed accelerometer). The MO method takes advantage of the usual response characteristics of an axially symmetric discus-like hull, wherein the motions around the mast axis are at higher frequencies. This frequency separation of the two motions allows the pitch and roll angles each to be uniquely related to the magnetometer outputs. The theory has been tested successfully aboard several hull types. Further tests are planned to confirm that the method will work when low-frequency, very long waves are being measured. Such waves produce very small slope changes, and thus very small magnetic changes, that might not be detectable.

The MO system, if proven accurate under all sea conditions, promises to reduce the initial cost of a directional wave measuring buoy by the price of the HIPPY sensor plus whatever cost reductions in the hull and assembly/buoy integration process can be achieved by not having to use the HIPPY. An additional benefit is reduced system complexity, which should improve reliability.[2]

Measurement of Currents from a Magnetometer

The magnetic vector inside the hull of a buoy can be projected onto the three orthogonal axes of a magnetometer, which can provide measurements of the three components of the vector. The bow (B_1) and starboard (B_2) components vary as a result of variations in all three of azimuth (A), pitch (P), and roll (R) angles. Generally speaking, however, the variations in B_1 and B_2 due to A occur at very low frequencies, whereas variations due to P and R occur at higher (wave) frequencies, with little overlap in frequency. Thanks to this separation, B_1 and B_2 may be high-pass filtered, and the resulting time series of $B_1(t)$ and $B_2(t)$ can be related to pitch and roll in a way that allows both to be determined. Once determined, pitch and roll can be used with the magnetometer outputs again to calculate buoy azimuth. Buoy azimuth, pitch, and roll can then be used (aboard the buoy) to determine time series records of east and north hull slopes. They can also be used with the outputs of three orthogonal accelerometers to compute earth vertical acceleration.

The acceleration, east slope, and north slope time-series can then be spectrally analyzed to produce what are known as co-spectra and quadrature spectra at "Fourier" bands. There are known relationships, based on linear wave theory, between the surface current vector (on the one hand) and the Fourier spectra and hull-mooring responses (on the other). By a complex invocation of these relationships, both the hull-mooring responses at each Fourier frequency, and the two components of surface current, can be estimated. Estimates of the hull-mooring response and these current components allow the wave spectra to be corrected for these factors.

Thus, *potentially,* surface currents can be estimated using a two-axis magnetometer and triaxial accelerometer.

Measurement of Winds Without Anemometers

A key observation made by NDBC buoys is ocean surface wind. On each buoy, wind speed and direction are measured by two duplicate anemometers. In this way, two objectives are achieved: (1) relliability is improved through the installation of redundant wind sensors: and (2) data quality is enhanced, since the winds from the two sensors may be intercompared. These objectives are important because the anemometers are the only buoy sensors with moving parts that are exposed to the marine environment.

In the last year, NDBC has demonstrated the feasibility of measuring ocean surface wind speed and direction from by-products of the NDBC directional wave measurement system. The technique to perform this measurement requires no additional sensors and, consequently, is very cost-effective. Field tests have proven the feasibility of the technique. As a result, NDBC now has a method, independent of the standard anemometer wind sensors, to obtain ocean surface winds. The resulting data may be employed routinely for wind sensor data quality assurance.

Recently, a vertical, flat fin was attached to one leg of the mast of a 3-meter discus buoy used for directional wave measurements (Figure 11). The fin provides the restoring torque to force the designated bow of the buoy hull to face the wind and to dampen yawing oscillations of the buoy. As a result, a rather stationary buoy hull condition can be provided during data acquisition. Therefore, the wind direction can be estimated from the direction of the buoy bow, which is expressed by buoy magnetic azimuth produced from an onboard magnetometer that is a part of the directional wave measurement system. Furthermore, the wind will generate drag on the buoy mast that, in conjunction with the mooring force holding the buoy on station, will cause the buoy to tilt in the fore and aft direction (pitch). Ocean waves and other environmental forces also affect buoy dynamics, causing pitch (and other buoy motions) to continuously vary. However, over the period of wave measurement sampling (20 minutes), wave-induced pitch will theoretically have a mean of zero. If the wind is relatively steady over the 20-minute period, then the azimuth (mean of maximum and minimum value) and the mean pitch that are produced by the directional wave measurement system can be used to estimate wind direction and speed, respectively.

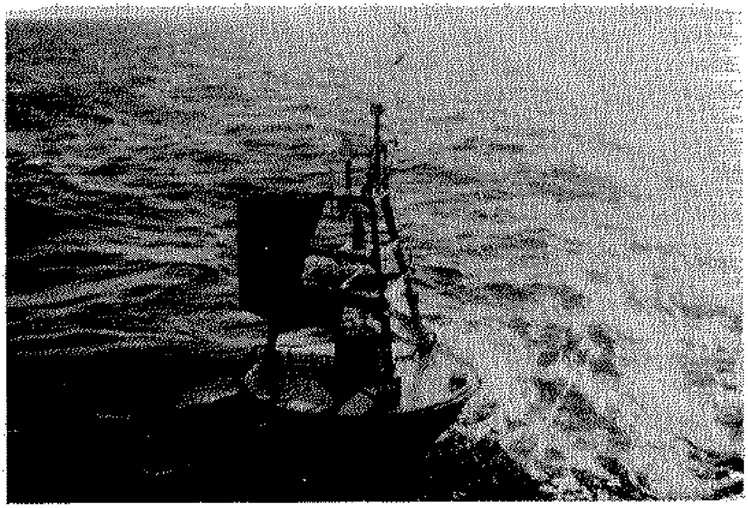


Figure 11. 3-meter buoy with fin

Three months of data collected at several NDBC directional wave buoy stations were used to verify the technique. For wind speed, an empirical equation relating wind speed to mean pitch angle was derived for each station. The form of this relationship was based on a theoretical analysis of the aerodynamic drag on the buoy superstructure. Using empirical formulae, wind speeds from buoy pitch were estimated and compared to anemometer-produced wind speeds. The effects of the steadiness of the wind on the difference between the winds from the wind sensors and the winds estimated from buoy pitch and azimuth were studied. For wind speed, variations in the length of the upper mooring chain, which affects the restoring moment of the buoy, were also analyzed.

Based on the results of these studies, about 85 percent of the estimated wind directions (from mean buoy azimuth over a 20-minute data acquisition period) differed no more than 20 degrees frrom the wind sensor directions. Under steady conditions in both wind speed and direction, 96 percent of estimated mean buoy azimuths were less than 20 degrees from the measured wind directions. Using the mean pitch technique, more than 94 percent of estimated wind speeds were within 2 m/s of the wind sensor measured wind speeds, irrespective of wind steadiness. Therefore, both the wind speed and direction estimating techniques have been demonstrated to work quite well.

Additional theoretical work has been done in an effort to improve the aerodynamics of the buoy mast-fin configuration. As a result, it is believed that new mast-fin arrangements could yield even better wind speed and direction accuracies.[2]

Acoustic Data Transmission

The significant improvements in the field of electronics have made it possible for more data to be collected, analyzed, and reported. Sensors, payloads, and transmitters can handle considerably more data now than they could just a few years ago. This increased capability has encouraged NDBC to explore the collection of more oceanographic data, such as conductivity, temperature, and current profiles. Progress is being made toward the acquisition of this data. Through the support of MMS, for example, acoustic Doppler current profilers are being installed on two buoys for deployment off the California coast.

Unfortunately, mechanical systems have not advanced as quickly as electrical. There are still difficulties in collecting data from thermistor strings that are associated with integrating the thermistors with the mooring line. To overcome these difficulties, NDBC is investigating advances in the acoustic telemetry of data. Acoustic data systems can be installed simply on buoy moorings or separate from them. Coupled with advances in battery technology, acoustic telemetry may provide a solution to difficulties in collecting oceanographic data from moored buoys.

Expanded Network

In support of the modernization efforts currently under way in NWS, an expanded network of moored buoys and C-MAN stations has been proposed. If approved, about 200 more buoys and C-MAN sites will be added between 1994 and the end of the century in support of the needs of weather forecasters.

SUMMARY

For over 20 years, NDBC has been collecting high quality environmental data from both land- and sea-based platforms. The future holds considerable promise. Through technological development and expansion, NDBC should produce steadily increasing amounts of data at decreasing cost per data word. These data, while collected primarily for NOAA and other government sponsors, will become even more valuable to those involved in seaborne commerce as the network expands to provide more complete coverage of the coastal areas of the United States, including Alaska, Hawaii, and U.S. territories.

ACKNOWLEDGEMENTS

The author expresses his appreciation to all employees of the National Data Buoy Center and the Computer Sciences Corporation (Data Buoy Support Contractor) who were involved in providing information for this paper.

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Evolutional Trends of the Coastal Zone and the Influence of Climatic Fluctuations

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ABSTRACT

The aim of this work is to consider the influence of natural climatic changes on the evolution of the Italian coastal zone and the possible implication, in modern times, of human activities on the configuration of the present coastline.

On the basis of the data collected along the Italian coast, we have formulated a general hypothesis about preventing coastal erosion in coastal zones around the world.

INTRODUCTION

Since the beginning of this century, everywhere in the world, coastal areas have been affected by a widespread regression which reached the critical stage after 1950. This situation is in contrast with the general trend of accretion that has affected the coastal zone in the past century. The 8000 kms of Italian coast show a large variety of shorelines.

Today, about forty-five percent of the Italian coast is threatened by a progressive and general degradation which is manifested primarily as beach erosion. This phenomenon seemed to worsen in the 1950s, after a long period of general beach stability.

Typical of this situation is the northern Adriatic coastal zone, where three physiographic units show the same decay in the same times: the Lagoon of Venice, the Po river delta area, the Romagna littoral near Ravenna.

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If one considers the intense interventions of man on its coasts for touristic purposes — demolishing the dunes to create beach areas, summer residential and marine areas; diminished fluvial sediment load to the sea by haphazard removal of riverbed material; increased subsidence caused by groundwater, gas and oil extractions in areas too close to the sea (Po Delta and Venice Lagoon) — one obtains a picture which easily explains the rapid instability of this coastal environment. This situation is present not only along the Italian coast but, in a greater or lesser degree, includes the coastlines of many other countries. This increased economic development, without consideration of the future impact on the environment, tends to worsen the already precarious situation even more.

From the end of the fifties to the present, the coastal area was used as an inexhaustible and indestructible property. Instead of managing this fragile region as a precious commodity which must last, the coastal zone was exploited without concern for the consequences or for rational economic management. These are the main reasons for the erosion, but we must also consider the effect of the storm waves that set off the erosion process of a coastline already compromised.

Big storms are generally connected with rigid weather conditions, typical of a general climatic worsening. In order to better understand the processes that control coastal evolution it is necessary to quantify the influence of climatic changes and the possible interactions with human actions on the landscape.

CLIMATIC CHANGES AND THE ENVIRONMENT

At the end of the last century, Bruckner published a study pointing out a sequence of climatic fluctuations based on the comparison of metereological data, which resulted in similar fluctuations in the same periods, in different parts of the northern hemisphere.

Scientific research performed in the last decades has pointed out that the general trend for the Holocene is towards a general climatic improvement compared with the last glacial stage (Wurm). In this general trend, we can distinguish in the Holocene some secondary climatic changes that have strongly influenced environmental conditions, acting on the physical and biological configurations.

Using geological, geomorphological, glaciological, paleobotanical, archeological and historical investigations, it has been possible to reconstruct the sequence of climatic variations with good accuracy especially for the historical times. Meteorological records permit a high degree of accuracy in the reconstruction from more recent times.

For historical times, in the absence of these records, it is necessary to support the reconstructions with correlations to historical descriptions for the most catastrophic events. Other terms of correlation are variations in ice fronts, changes in vegetation, variations in the features of rivers, lakes, marshes, the products of crops, either the appearance or the disappearance of animal and plant species, the shape and thickness of the annular rings of trees (dendrochronology).

Studying the variations for the ice front in the Fernau Glacier (Austrian Alps), for the last 3,000 years, five cold and humid periods have been identified. They produced in Europe and in the Mediterranean Basin several hydrogeological troubles. The length of time for each period: 1400-1300 B.C., 900-300 B.C., 400 -750 A.D., 1150-1300 A.D., 1550-1850 A.D.

It has been found that for glaciers the reply to a variation of mass balance is always delayed a certain amount of time that depends on the glacier features. However, it is evident that the stages of advance on the glacier front follow the presence of particularly big snowfalls (above average values) connected with particularly low temperatures (under average values), especially during the ablation season.

It is possible to conclude that in the periods in which the glaciers advance we find peculiar meteorological and geomorphological conditions: increasing rainfalls, decreasing temperature and a resulting higher speed in geomorphic processes that, acting on the lateral slopes and on the lowest part of the valley, modify the landscape. Great soil erosion means a larger transport and deposition of fluvial sediments. Therefore there will be variations in the water courses associated with morphological variations on the river bed.

In the big alluvional plains, such the Po plain (Italy), associated with these processes, the rivers tend to become hanging rivers because of the change in depth of the riverbed. It has been found in many European areas and in the Mediterranean Basin that as a result of climatic changes (increasing rainfall) there was the phenomenon of overflowing on the lateral sides of the river valleys, generated by the increased discharged and sediment transport in the river streams.

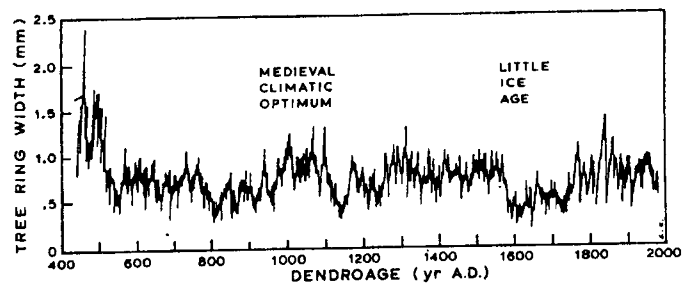

Figure 1. Dendrocronological standard curve: Northern Sweden from 436 A.D. to today (Bartholin, 1984)

When the climatic configuration tends again to normal conditions, stable for long periods of time, the hydrography will assume a particular pattern without short term variations. The river beds will become deeper, rivers will lose the hanging river configuration and big floods will be rare. Up to now the reasons for the progradation of rivers were simply found in deforestation on the mountains, and the lack of defence works to stop the removal of materials from the soils for the benefit of agriculture. The deltas progradation is a phenomenon that is common not only in Europe but, in general, in other parts of the world. Without doubt man's activity is a concomitant cause in this general trend. In fact, one is sure that in the period 1550-1850 the "little ice age" occurred, as testified by two advances in the extension of the Alpine glacial termini. These two different phases had their peaks at a distance in time of about 200 years: the first phase in 1600-1620 and the second in 1800-1820. Regarding the wide spatial distribution of ice during the first phase, dendrochronological studies also have confirmed that all European glaciers extended from the Scandinavian area to the Alps. The dendrochronological standard curve in Figure 1 points out the same climatic changes in the same periods in Sweden from 436 A.D. to the present.[1]

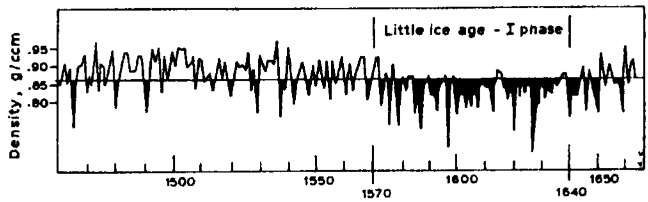

Figure 2. The curve of the maximum latewood density values for one tree which grew in the period 1460-1660 in Europe (F.H. Schweingruber, 1988)

It is well known that the latewood density values give information about the weather conditions in summer (Figure 2) within this "large scale" climatic cycle; shorter periods (10-35 years) of cold, rainy weather alternated with warm, dry periods are known as "Bruckner Cycles." The reclamation works done in the Po plain between the first half of 16th Century and the early years of 17th Century have been strongly tested by the "little ice age."

The increased rainfall caused slumps, landslides and similar phenomena in the areas located in the hills and in the mountains. This produced a big amount of clastic materials carried to the sea and caused the filling by sediments of river beds. Therefore one knows that close to the end of 16th Century many ports on the Adriatic Coast were filled up by sand.

Around 1850 the "small ice age," with its exceptional values of climatic degradation, ended. Despite this, small climatic fluctuations of 10-35 years continued with cycles of cold/wet and warm/dry, but with minimal and maximal values well above temperature observed during the "little ice age." It is very interesting to consider how the climatic changes noted in Europe are present, in the same periods, everywhere in the world (Figure 3). This general correspondence becomes more evident considering some regional areas: Figure 4 shows the correspondence between Central England and Shanghai temperatures.

Utilizing a comparison of different series of parameters (rainfall, temperature, dendrochronological curves, etc.) in different parts of the world, it is possible to show the coincidence of a climatic trend in the same periods. The presence of a warm/dry period is particularly evident today, beginning in the middle 1970s, not only in Europe, but in all the Northern Hemisphere.

This dry period, distinguished by low rainfall and warm weather, caused increasing desertification in Africa (Sahel area), Middle East, Western India, Northern China and Japan. It means that these phenomena are not regional, but of planetary interest and they continue to develop and to produce a strong influence on the natural environment.[20]

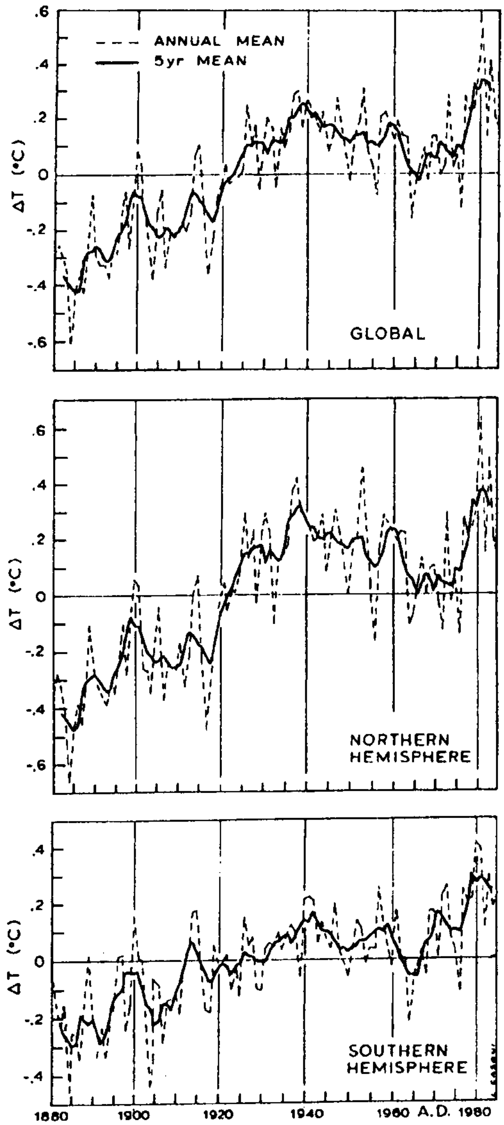

Figure 3. Global and hemispheric surface air temperature change from 1880 to 1980 (Hansen, Lebedeff, 1987)

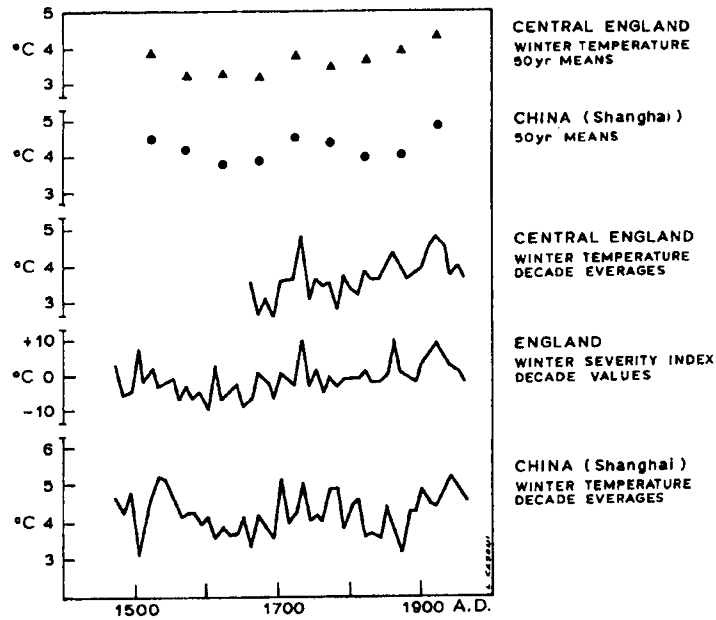

Figure 4. Comparison between the Winter temperature records for central England and China since 1500 A.D. (H.H. Lamb, 1982)

THE NORTHERN ADRIATIC LITTORAL EVOLUTION

The features of the Northern Italian Adriatic coast from the Emilia-Romagna littoral to the Venice lagoon are very different (Figure 5). The Emilia-Romagna coastline between the Po river delta to the north and the Gabicce promontory to the south, constitutes a physiographical entity characterized by a wide sandy littoral, with the Po plain behind, interrupted by the sea outlets of numerous, very modest rivers coming from the Apennines nearby.

The Po river delta follows covering a surface of 73,000 hectares of which 60,000 are reclaimed land and the remainder are brackish lagoons, with dams or open foreshores and emerging sandy banks. The third physiographical unit is the Venice lagoon, with a thin stretch of littoral that extends for some 50 kms separating the lagoon of Venice from the Adriatic Sea.

With regard to the long-term evolutionary trend, the comparison of data on the width of the backshore, relative to the past times, indicates, for whole area, a general increase of the emerged beach (with maximum values corresponding to the river outlets) (Figure 6) up to the beginning of this century. After the first decade of 1900, only some sectors continued to increase, but at a speed decidedly inferior with respect to the past. The greater part of the littoral presents, first of all, an arrest of the increase followed by a regression of the shoreline which is accentuated mainly during the fifties, with ever increasing speed and intensity up to the 1970s.

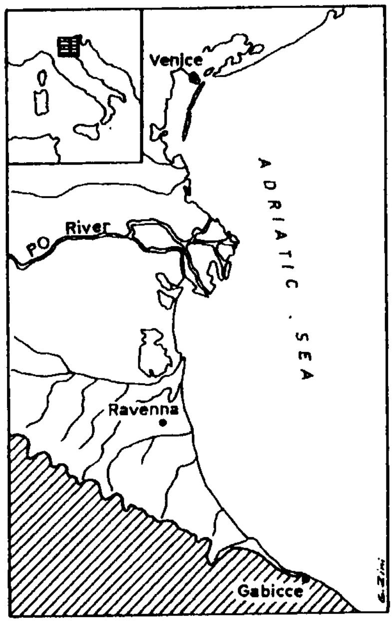

Figure 5. The coastal zone from Gabicce to Venice

In particular, this present negative trend is evidenced in the Emilia-Romagna littoral by comparison of the increasing bottom slope from 1954 to 1978 (Figure 7). This situation, producing a general regression of the shoreline, is due to storm waves action on a littoral without natural nourishment by the rivers. The combination of massive human activity with a bad climatic period (high frequence of storms) has produced an explosion of erosive phenomena along the Emilia-Romagna littoral.

In ancient times the situation was very different for the whole area. The uncontrolled river system, subject to intermittent ruinous flooding, caused serious inconvenience to the first human settlements in the Po plain. Periodical breaches, caused by floods during periods of wet weather, modified the hydrology and morphology of the Po River Valley and influenced the configuration of the delta.

In Roman and successive times, action began to control and correct the course of the river through the construction of canals and dams. The evolution of the Po delta is characterized by two different depositional phases: the first phase is identified by ten cuspate deltas that have been substituted by lobe-deltas.[10] We find the oldest lobe-delta in the 12th Century caused by the breach of "Ficarolo," when the Po river central mouth moved northwards.

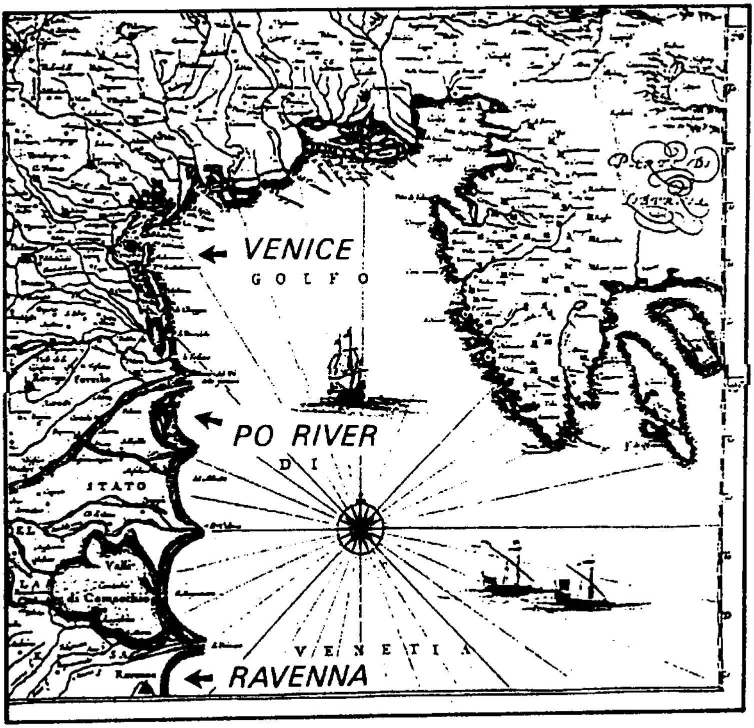

Figure 6. Old map (1662) showing the developing into the sea of the river mouths (Adriatic Sea - Italy).

The growing rate of the Po delta area has been changeable: from ancient times up to 1600 it was close to 450 m/100 years. From 1600 to the present the rate has an average value of 7 km/100 years. From Figures 8 and 9, one can observe that the greatest advancing of the deltaic system is during the "little ice age" from 1600 to 1820.

The dynamic advancing of Po river delta is quite simple. The sediments carried by the river to the sea are discharged at the river mouths, where they are reworked by wave action to form sand bars both at the front and at the sides of the mouths. If the supply of sediment is great and constant the bars tend to grow up and to emerge; they are then fixed by marsh vegetation and join the mainland. Therefore we obtain an area of lagoons and small pockets of water behind the delta system. Such a process can be cyclical.

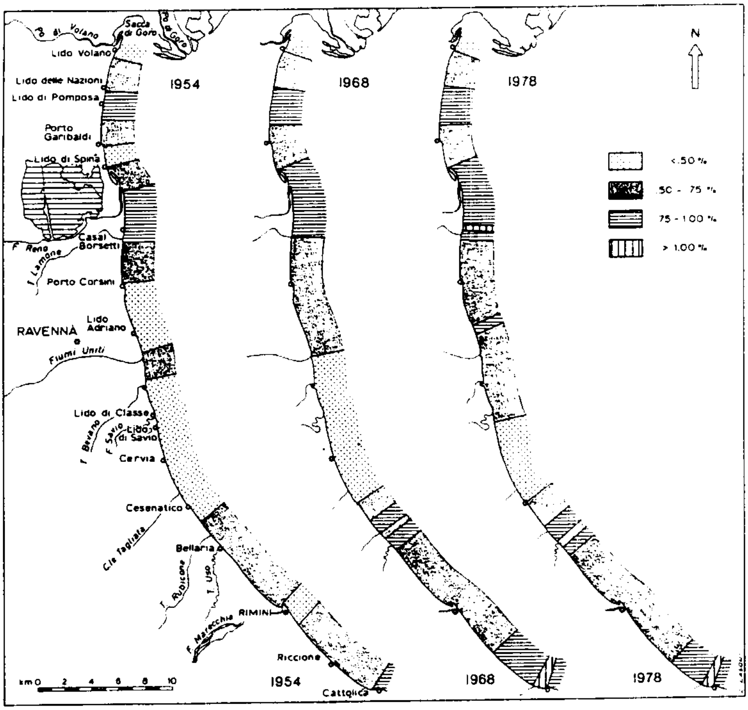

Figure 7. The Emilia-Romagna littoral. Variations of the bottom slope from the shoreline to the 5 m isobath (Marabini, 1985).

Since 1550 at the beginning of the "little ice age," the great and constant supply of sediment towards the Venice lagoon undermined the existence of the lagoon. For this reason, around 1600 the Venetians moved the Po mouth southwards by artificial canals in the area of Porto Viro. Since that time the delta has continued to grow towards the sea to form the present configuration.

Figure 8 shows the long term evolution of the shoreline from 1000 B.C. up to the present time for the Po river delta and the Emilia-Romagna littoral, near Ravenna. The comparison among the shorelines points out general advancing from 1600 up to 1750 and 1820 during the "little ice age." This situation is particularly evident upon examining the cartographic data for the Po river delta from 1600 to the present (Figure 9). Maximum advancing of the shoreline is evidenced by the 1953 survey. Then, between 1960-70, an inversion occurs in the trend: this means that the coastline moved back towards the land in the external area of the delta.

At present the water bodies tend to be filled up by sediments and therefore the coastline is again moving towards the sea. It should be pointed out that the actual configuration of the coastline is different from that one surveyed in the 1950s: in fact, it has moved inland.

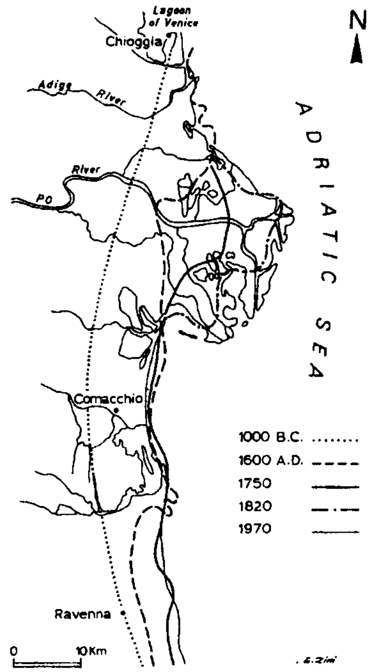

Figure 8. Evolution of the Po river delta (Nelson, 1970)

The outer part of the delta has been very unstable in the period 1960-70. This is connected with a general tendency to coastal erosion that has affected all the Italian coasts, especially the Adriatic ones. It is interesting to note the correspondence between the major developing of the Po delta system and the cold/wet weather conditions. It is particularly evident for the Ficarolo breach (XII Century) due to the bad climatic period following the warm/dry medieval climatic optimum (see Figure 1). Another example is the large advancing of the Po delta, building from 1600 up to 1812 (see Figure 9) during the "little ice age" (see Figures 1 and 2).

In the present time, from the end of the 1970s, the warm/dry weather without abundance of rain, floods and storms points to a quiet situation along the coast after the precedent cold/wet period. The difference with ancient times is that the last critical period, around 20 years, produced a regression of the shoreline instead of an advance. The violence of the storms waves prevailed over the natural nourishment of the sediment yield by the river. This new result is due to human activity on the coastal zone (artificial removals of riverbed material, destruction of sand dunes, subsidence by the artificial extractions of fluids, etc.), that diminished the sediment yield to the sea and permitted prevailing of the storm attack. The modality of the Venice lagoon evolution shows some differences, even if subjected to the same climatic changes valid in the southern littorals.

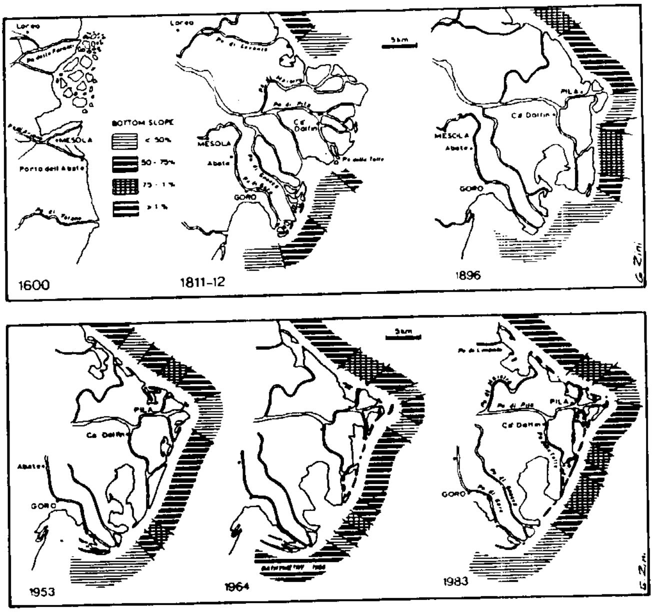

Figure 9. The Po river delta from 1600 to 1983 with the variations of the bottom slope from the shoreline to the 5 m isobath (Cabognin, Marabini, 1989)

The Venice lagoon originated about 6000 years ago and outlined the coast in approximately the present position. Of course, the lagoon morphology was subjected to the great mutability of those factors which has generated and developed it during the ages. Among them, the activity of the lagoon tributaries was determinant. The Adige, Bacchiglione, Brenta, Sile and Piave rivers flowed into its basin; they guaranteed the brackish water, but reached a large amount of sediments during the floods.

The cores show an alternance of sediments typical of marshland and lagoon for the most ancient times. The first historical accounts are attributed to Paolo Diacono; he described the flooding of 589 A.D. This changed the course of several rivers, among them the Brenta and Adige. So powerful was the intensity of flooding that the town of Julia Concordia, 30 km to the NE of the Venetian lagoon, was destroyed entirely and left covered by a soft water marsh.

Peat deposits seem to have developed mainly in the central and southern part of the Venetian lagoon, at the former mouth of the Brenta river. In the northern part of the lagoon, on the other hand, the rush of soft water appears to have been less abundant than in the central or southern part.

This event, particularly catastrophic, is not isolated because the entire period between 450 and 650 A.D. appears, from historical accounts, to have been very rainy in Venetian areas.

Such a process led unavoidably to the disappearance of the lagoon basin, making it become a permanent emerged area joined to the Venetian plain. Considering the lagoon the best defense of Venice, the Republic of Venice began to carry out several hydraulic works to preserve it: mostly, the diversion of the major lagoon tributaries into the sea, the location of the sea entrances, and the digging of canals for inland navigation. The diversion of the Po river from northwards to southwards in 1600, during the "little ice age," is an example of the military and economic necessity to maintain the navigability of the lagoon.

These age-long works, impressive at the time, were started in the 14th century and completed in the 19th century. Though they avoided making the lagoon a marshland, nevertheless the natural evolution tendency was inverted, and with the passing of the time, sea characteristics began to prevail more and more clearly. The precarious condition of the lagoon environment is made still worse by the deterioration of the littoral which is of paramount importance because it is the only slender, fragile bulwark against the attacking sea.

At the present time the thin littoral, separating the lagoon from the Adriatic Sea, is covered by defence works to combat the waves, but these are not always sufficient to defend the lagoon. The comparison among the 1954, 1968 and 1982 bathymetrical surveys up to 5 m depth (Figure 10) show a notable increase of the bottom slope from 1954 to 1968 along the whole shoreline. Between 1968-1982 a stability around the 1968 negative values, except for local variations along the Cavallino, is observed. The first period was characterized by meteo-marine conditions negative for shore stability. They culminated at the end of the 1960s with several sea storms, some of which were particularly destructive to the man-made shore protection structures.

The three physiographic units of the italian coastal zone are very different, but their evolution in ancient times shows a high influence of climatic fluctuations. At the present time, this influence does not disappear but more and more massive human activity presents a new complication for the final configuration of the present coastline.

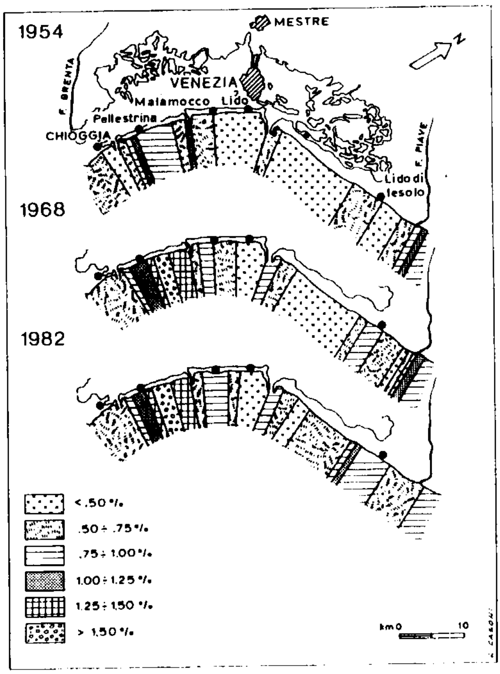

Figure 10. The littoral of Venice. Variations of bottom slope between the shoreline and the 5 m isobath (Carbognin et al., 1985)

CONCLUSION

The effect of climatic changes on the evolution of the natural environment is of primary importance today, as in the past. While for glaciers, rivers and vegetation there is no problem recognizing climactic effects, for the coastal zone the configuration is more complex.

This happens, not only because of the strong human influence that is too often present all over the world in coastal areas, but also because these zones are in a delicate dynamic equilibrium. In fact, this area is the boundary between sea and mainland, and the agents controlling this equilibrium are the fluvial sediment supply and the distributing of these sediments by wave action generated on the sea surface by wind.

One cannot simply state that cold/wet climate induces a greater precipitation with a greater sediment supply to the sea, and therefore a shoreline advancement. In fact, these weather conditions imply even a greater frequency of strong storms that may cause shoreline regression. Examining the evolutional trend of the northern Adriatic coast from Middle Ages until today and the close connection of their evolution with the general advancing and regressive trends for the coastal zone, one is able to formulate an hypothesis based on the evidence given by the data.

In a period of cold/wet weather, coastal equilibrium is controlled by the relationship between the large sediment supply by rivers and frequency of strong storms. If the sediment supply is greater than the removal of sediments caused by wave action, the beach becomes wider. Instead, if the sediment removal is bigger than the supply, the coastline moves backwards. In periods of warm and dry weather, the sediment supply to the sea is less and storms are rare. Therefore, the tendency is that the coastline moves around an equilibrium point or moves slightly seawards. From that one can say that cold and wet weather conditions are determinant for coastal evolution.

The reason for major changes in the coastal zone from 1600 up to the last century is that the fluvial sediment input, connected with the "little ice age" climate condition, has been much bigger than the output caused by the attack of waves in storm conditions. Then smaller climatic variations, with a 10-35 year period, have induced a progressive reduction in coastline advancement since the beginning of the present century, reaching its full development during the 1950s, when the sediment supply, typical of cold periods, became inadequate because of human action on the coastal zone and on the areas lying behind. This caused an environment out of balance because of the lack of sediment supply by rivers, such that wave action has become the control parameter causing erosion. This last event is true for the whole examined area, influenced by massive human activities and generally, of course, for littoral stretches with the same conditions at the present time.

At present time there is a period of warm and dry weather, distinguished by low rainfall and low frequency of storms, that follows the cold/wet period ended during the 1970s. Therefore it looks like the erosive tendency on the Po delta and on the Adriatic Coast has disappeared and the coastline is stable everywhere or tends to move towards the sea. This happens in areas where coastal defences have been built (at present more and more frequent) and where coastal works have not been constructed.

This does not mean that the threat of erosion is overcome; in fact by examining past climatic fluctuations one would find that we are going towards a period of cold and wet weather. Therefore, an increase in storm frequency is expected, along with destructive action of the sea. Because of the low sediment supply due to human activity, that may cause coastal erosion as it occurred in the past.

From the above, one can say that while in the past coastal equilibrium was controlled by the natural events, at present they act in union with the effects caused by human action. This in an environment where the dynamic equilibrium was already delicate in itself.

This configuration is valid for the northern Adriatic coast as well as for the coastal zone in general, where there is massive human activity. As geologists, we cannot comment on the causes of climatic fluctuations; however, as seen in Figure 11, it is possible to note the correspondence between sun-spot activity and climatic change during the last 300 years. It is evident for the second phase of the "little ice age" and even for following times.

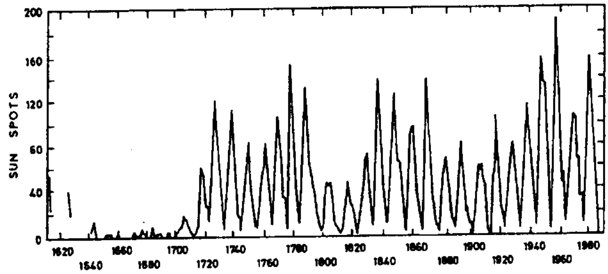

Figure 11. Sun-spots cycles during 1610-1985 (Williams, 1986)

This is only the first attempt to examine the Adriatic coastal areas, to understand and predict the evolutional trends, under a new and more complete point of view of the coastal zone, which is a natural and delicate environment more and more important for economic activities.

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The Megabight Barrier/Way: Ocean Engineering Solutions to Eastern Seaboard Needs

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ABSTRACT

The populated coastal areas of the Eastern seaboard have multiple needs resulting from population growth, intensive development, and inadequate past waste storage practices. New problems include the possibility of larger, more frequent hurricanes and the need to find routes for high speed rail systems that don't destroy valuable urban real estate.

TRANSYSTEMS INC. proposes a concept to meet these needs: the multifunction MEGABIGHT BARRIER/WAY project to create a string of offshore islands that could safely contain all the past and future waste of the region, linked by a structure that becomes a storm surge barrier when needed. The filled islands create "new land" for a variety of uses, relieving development pressures in urban areas. The overall structure, paralleling the coast (e.g., from Norfolk to Nantucket: The "MEGABIGHT") in a curving arc, becomes the ideal location for high speed rail systems such as the MagLev train.

The benefits of this concept include improved ocean and land environments, storm surge protection, safe waste recycling and disposal, new commercial and residential sites plus ocean-access recreation, deep water ports, mariculture facilities, hazardous material storage, power plant and incinerator and desalination sites, oceanography/mariculture/environment training and research lab sites, siting for unpopular facilities, air/STOL port sites, safe oil exploration and pumping, wave energy recovery and/or wave tripping and an intercity transportation way. The BARRIER/WAY project would create many jobs in the region, and would improve the country's economy. The revenues produced by the land created and services performed would pay for its construction.

International Perspectives on Coastal Ocean Space Utilization
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Subsequent sections of the paper summarize the rationale for large-scale projects in a shrinking world; how multiple functions enhance project cost-effectiveness; the land-based approach limitations that justify offshore projects; and briefly describe some offshore projects and technologies that are applicable to this project. Some details of the MEGABIGHT BARRIER/WAY concept are given, but cost information has not been developed yet.

Public support for such large-scale activities must be developed, creating project acceptance and investment. Actions that would also create more oceaneering jobs are recommended and should be undertaken now:

- Initiate a full systems study of this concept, integrating all relevant projects previously proposed, that includes interfacing with development and regulation agencies,
- Explore private initiatives for project implementation; develop new funding instrumentalities to stimulate investment,
- Create an Oceaneering TEXPO center/network for public awareness and implementation support.

One of the most pressing need that coastal cities must address quickly is the protection — and recovery — of both the ocean and land environments they depend on. We now see the effects of our cavalier attitude towards the land/ocean biosphere; the diminishing resources the ocean provides, the degraded environment that makes recreation unpleasant, and the dangers it presents to our very survival. For resource availability, health safety and even for aesthetic reasons we must reverse the environmentally destructive practices of the past, and even try to return the land/ocean environment to some semblance of its former condition. We may not achieve pristine status but with effort and thought we can dramatically improve today's sorry state.

One of the most continuing and pressing problems is the disposal of society's overabundant waste. Land-based waste disposal sites are fast approaching capacity, and as they grow in height they become eyesores. As development fills up the land with residences and places of business, generating even more refuse, new disposal sites become unaffordable (if any can be found) and the public resistance makes approval nearly impossible. Inland, less populated states that once welcomed refuse are now charging considerably more while preparing legislation to stop the importing entirely. And increasing numbers of people are complaining about the problems of the existing sites in their communities, and expressing fears of groundwater contamination, etc.

Sewage has usually managed to exceed our planned capacity for processing; discharges of some raw sewage still occur, especially when rainwater floods the common collection system, while sludge from the treated sewage is "quietly and/or anonymously" disposed of at sea. And dredging spoil, tainted with toxins, metals, PCBs, etc., should not be simply dropped back into the ocean.

As the population of the urban coastal area grows, we are experiencing increasing demands for land space to support recreation, commerce and new residences. At the same time we are faced with growing outcries against certain facilities or land uses that the public does not want near their homes and communities: the NIMBY phenomenon. These unwanted sites can be grouped into three threat classes:

• Possible accidents that would damage or destroy life and property (e.g., LNG explosion; nuclear plant meltdown ...),

• Degradation of the environment from continuous emissions (e.g., (incinerators; power plants; airports ...),

• Sociologically undesirable facilities (e.g., jails; drug rehabilitation centers; mental hospitals ...), which make these facilities or services increasingly difficult to locate in any densely populated community.

Another "threat class" that should not be overlooked is the unrealistic and unbridled consumption of on-land open space, a subset of the general concern for proper utilization of our limited land surface area. As population grows and the demands for land increase, some allocation or priority ordering will have to be employed in order to insure that there is sufficient area for the necessary functions that can only be performed on the land surface. Prime examples of these land-requiring functions are agriculture, forestry, outdoor recreation and watershed collection areas for reservoirs. Virtually all other functions can be performed elsewhere; i.e., underground and on or in the ocean. Continuing to assign land space to these other non-surface-essential functions simply creates a greater problem for the future (and usually decreases the value of the land used). The Japanese plan to create underground cities recognizes this. Their land shortage has forced the need for such choices now; our decision-making time on land use is fast approaching.

There are other area needs that should be addressed as well; not as undesirable but still pressing:

- The continuous demand for land near the shore for many uses, including training & research facilities for oceanography/mariculture/environment,
- New public access to the ocean for recreation,
- Deep water ports (supertankers and naval bases),
- Interstate/international (pipe) shipment of energy and material,
- High speed intercity ground transportation pathways,
- Airport and STOL port sites,
- Modernizing water's traditional role in transportation of goods and people,
- Replenishing the ocean's harvest — through mariculture,
- Shore protection against hurricanes,
- Exploration and development/pumping of offshore energy fields.

We are now being forced to clean up the mess created in the past by our "disposal" techniques, while trying to anticipate future problems that may require protective steps. Such activities, however, could have a beneficial impact on another pressing need: to "jump-start" the northeastern economy.

THE MULTIFUNCTION MEGABIGHT BARRIER/WAY CONCEPT

This concept grew from the simultaneous consideration of the multiple needs of most cities on the Eastern seaboard, but especially the plight of New York City. The city's most pressing, ongoing and "legal" problem is the 27,000 tons of business and residential solid waste collected each day. 10,000 tons are shipped out of state (but for how much longer?), and about 3000 tons are recycled or incinerated, leaving over 14,000 tons to be "disposed of" within the city limits. Uncompacted, this amounts to about 140,000 cu. yds. per day, which would fill 10 floors of a World Trade Center tower. Each month, then, the city must dispose of enough refuse to fill two WTC towers! Over the past several decades there have been suggestions to create offshore islands to house this waste; the BARRIER/WAY concept began as a restatement of that idea.

But the city may be facing another severe threat in the near future, so this concept was expanded to cope with this also. Atmospheric warming is expected to produce an ocean level rise, but before this becomes a problem we can expect to be battered by larger and more frequent hurricanes if some meteorologists' warnings are correct. The impact of a Cancun- or Charleston-class hurricane on the Eastern seaboard, especially the New Jersey and Long Island coasts, would be difficult to overestimate. So, if a higher frequency of large storms is reliably forecast, we will likely need some storm barriers, similar to the Dutch Delta Plan at Oosterschelde. This concept recommends paralleling the Eastern seaboard in a 450 mile long arc, from Norfolk to Nantucket, with a string of islands that are waste repositories, and that anchor movable storm surge barrier structures.

Clean fill (from, for example, excavated city streets) could be used to bank up around interlocking steel/concrete piles driven into the ocean floor to form hollow, offshore islands. This volume could then be filled, cell by cell, with the overabundant solid waste from our area (including existing landfill site material, sewage sludge and dredging spoil), after first processing to remove recyclables, and then sanitizing and solidifying. "Trash-sure Island" would then be topped with more clean fill, creating new lands for an airport or STOL port, recreation areas, marinas (and possibly even beaches), commercial and residential sites, and those facilities that are not wanted ashore. These would all function to produce the revenues that repay the cost of the construction.

These "islands" could also be used for locating hazardous operations such as the unloading of LNG; the liquid is stored there, and converted to gas for piping to shore as needed, as proposed by Hydro-Icona Inc. The islands could also be the sites for power plants and incinerators, and other unpopular uses.

As in the Delta Plan, the islands and barriers would be interconnected by a roadway, providing all necessary technical maintenance and commercial access as well as allowing recreation driving. Such a roadway promises to allow high speed "ground" transportation; the barrier could offer a smooth, right-of-way for a MagLev train between the major coastal cities of the Eastern seaboard. This could be the optimum location for the MagLev system due to its need for relatively straight, smooth track paths, and new concerns for the effects of its magnetic field and EM radiation on anyone living near the tracks. Feeder connections would link the coastal cities to the MagLev run.

An additional consideration would be the placement of the transportation way between the islands. Would it be better above the surface (requiring ship clearance), or perhaps below the surface, in a floating tunnel such as the approach now planned in Norway to span the mouth of a Fjord. The tunnel, actually floating one hundred feet or more below the surface and tethered to the bottom, would present no barrier to passing ships (submarines would be skilled enough to detect and avoid the tube), and would protect the trains from inclement weather. Such tubes would have to be evacuated to permit very high speed travel over long distances (cf.: Dr. Henry Kolm's proposal for Magneplane that could achieve supersonic speeds within an evacuated tube).

Such an offshore string of islands and structures would allow development and placement of wave energy recovery devices which could meet the (electrical) energy needs of the islands' activities, and might just provide enough power to evacuate the tubes for supersonic travel.

Given this structurally sound chain of islands and barriers across the Eastern seaboard it would seem feasible, and desirable, to create some permanent, floating islands that could be anchored in the lee of the island/barriers, and that would (re)create a fish breeding area out in the relatively clean ocean waters. Rigid floating structures, linked by elastic connection to form a flexible mat that could heave with the waves (but they would be minimal in the lee), could actually support mud and aquatic plants, creating artificial wetlands. Mechanisms could be devised to vary the buoyancy of the island units, thus simulating the tides. The normal rainfall on the islands could be retained by their cover, helping to maintain nature's salinity balance. Used auto tires (rims removed) could be hung below, to provide hiding places for smaller fish, and we could even explore the Japanese method of growing oysters and other shellfish suspended in ropes or net tubing. All in all, this could be an effective and efficient way of restocking depleted oceans. Another interesting possibility occurs when considering offshore oil exploration and eventual pumping. The safest way to accomplish this is to have the rigs mounted on islands in the chain, so that spills would be contained; the oil brought up could even be processed there (at a refinery on one island). The products (or the crude) could be pumped ashore through protected pipes mounted to the BARRIER/WAY or feeder rail lines, eliminating the loading and unloading of tankers (except for export). These islands would permit slant drilling to develop the sources if their locations could approximately coincide with the oil fields.

The concept, then, is the creation of a chain of islands, with surge barrier structure in between, creating new land and a path for high speed transportation and safe (pipe) shipment of energy materials interstate. This barrier/way concept could be expanded to the entire Eastern seaboard, and to the Gulf of Mexico (down to Cancun; with tie-line across Northern Florida) and to the West Coast (where the barrier may not be needed, but to meet the offshore drilling/pumping and water desalination needs).

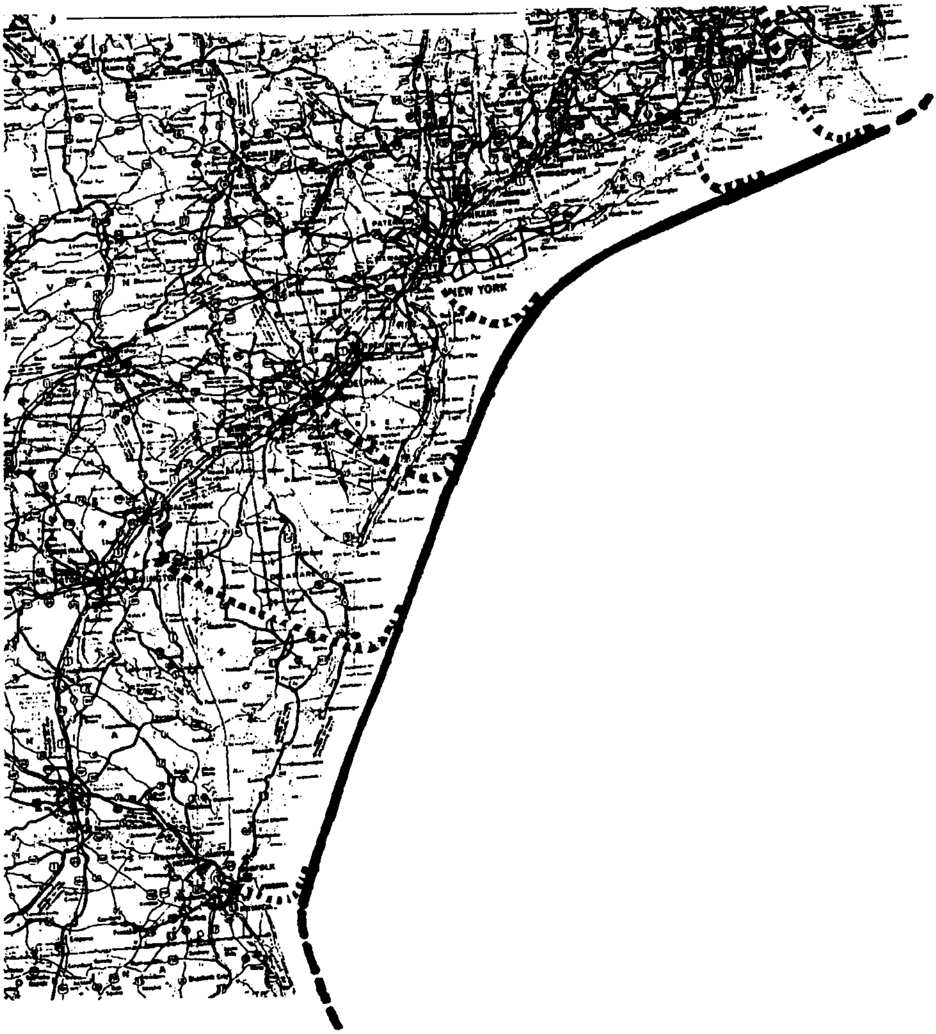

Figure 1. Proposed Siting of the MEGABIGHT BARRIER/WAY

Figure 1 shows an approximate location for this Barrier Way (five to ten miles offshore — below the horizon); the rail connections from the major cities along the way (that could be underground/underwater floating tunnels) are shown as dashed lines.

BENEFITS OF THIS CONCEPT

The MEGABIGHT BARRIER/WAY concept offers hope for the future of coastal areas and generates revenues from these activities to pay for its construction through:

- Improvement of both Ocean and Land Environments
- Storm Surge Protection
- Waste Recycling & Disposal Sites
- New Sites for Commercial & Residential Development
- Supporting Mariculture Facilities (floating wetlands)
- New Recreation Areas & Ocean Access
- Hazardous Material Storage (LNG)
- Power Plant & Desalination Plant Sites
- Oceanography / Mariculture Training & Research Labs
- Isolation / Rehabilitation Community Sites
- Environmental Research Facilities
- Airport / STOL Port Sites
- Opportunities for Deep Water Ports / Naval Base Sites
- Transportation Way - Road & MagLev
- Safe Path for Material & Energy Transfer (by pipe)
- Leakproof Bases for Offshore Drilling/Pumping
- Wave Energy Recovery / Wave Tripping

The concept would benefit coastal cities and states of the northeastern U.S. and industries supplying construction materials, resulting in economic benefits to the entire region by increases in commerce and trade. It would create new opportunities for business, for research and for the general public.

SUPPORTING CONSIDERATIONS FOR THIS CONCEPT

Rational for Large Scale Projects in a Shrinking World

We are said to live in a "shrinking" world, a misleading phrase that actually refers to the speed of communication and travel that have made all parts of the world seem closer. The principal result of this "development" is that we are becoming more interdependent with the other countries and cultures that share

Spaceship Earth. World interdependence, if properly addressed, requires that we must consider the impact on others of any national, regional and even local undertaking. Therefore we must expand our thinking and planning to include these considerations. This generally enlarges the scope of the problem — and solution — that is considered.

Additional considerations are the growing population of the world, and the population shift from farm to urban area. It is more efficient to meet the needs of more people with a larger system that offers greater efficiency and economies of scale. The rush to the urban areas creates the demand for centralized functions that, in turn, is best met by large projects.

In the past, unfortunately, planners and developers have narrowly defined and restricted their considerations in order to quickly complete some project, and have been allowed to ignore the "externalities:" any non-direct components or effects that don't impact the narrowly-defined performance of the project. The legacy of these "blindered" activities are all about us to see (e.g., housing projects that did not consider the impact on traffic and infrastructure services that would result). We can no longer afford the luxury of such shortsighted actions, and now must go back and correct the mistakes and shortfalls of the past. And many of these mistakes have been on a large scale, which will require even larger-scale corrective action. With the pressing problems we face today and tomorrow, there is no time left to do things sequentially; that would be too costly. In addition, problems left untended may cancel, or nullify, results from the solved problems.

A more positive consideration in vast undertakings is the realization and experience of the ECONOMIC BENEFITS that derive from large projects. Authoritative studies have shown that there is a 10 to 15 times multiplier to the local economy for every dollar spent on a public project! Such a funding multiplier could do wondrous things in bringing us out of the recession now taking hold; our local and national economies need the massive injection of activity and hope that such projects can provide. And even before the projects are underway, there would be enormous PSYCHOLOGICAL BENEFITS from an announced study of a major project; this would also refurbish the Utopian image of our society that is now so tarnished.

There are also POLITICAL BENEFITS from the large-project approach. Most political leaders are more versed in negotiation than in problem solving. As administrators, they are inexperienced in dealing with new, large projects or solutions. As C. Northcote Parkinson so aptly explained, administrators tend to agree more easily and quickly with large-scale projects. And a large solution that spans several political jurisdictions requires the political leaders of each to become part of a team, so they are less likely to exert undue influence individually.

We would be remiss if we did not address the public's fears of large projects, especially if they are planned in its back yard. As a practical consideration, people are very concerned about the proclivity of large projects to develop cost overruns, which usually raises their tax bills. They are also afraid a large project could get out of control and develop a life of its own; become unstoppable. Most of the lay public are boggled by complex problems that won't yield to simplistic approaches; many are afraid of "high technology," probably because of their fear of what it might do to their immediate job security. And they have fears that project management can/will be non-accountable for their actions, especially if things go wrong!

Our society has even "progressed" to the absurd point that many people are "bored" with technology, or perhaps just its slow, real-world pace, since they have seen more advanced doings in movies and television. Perhaps a more important reason for their bored attitude is that they do not see any direct, immediate benefit from most technical projects. And, unfortunately, some projects have been abandoned after years of use and (mis)maintenance, leaving hollow shells that become occupied by society's unfortunates and outcasts; the low-income housing projects recently razed fit into this category.

The largest projects of the past, such as China's Grand Canal and the Roman 3rd (Augusta) Legion's success in halting (and reversing) the northward spread of the Sahara with tree planting watered by aqueducts, have been benevolent to the populace of the countries undertaking them, providing water, transportation paths through difficult terrain, etc. These projects were very visible, which helped the public see the activity and the immediate benefits to themselves. Offering the American public knowledge of these vast, past activities would be beneficial in helping them to see and appreciate the benefits of large modern projects.

Due to the magnitude of the problems we face, and the scale of the "slate on which they are writ" as the world population grows and migrates towards urban areas, these offshore/ocean projects must necessarily be large in scope. We have no choice but to plan for, and embark on, the large projects that could cope with these immense challenges we face.

Multiple Functions Enhance Project Cost Effectiveness

Given several problems, and near-equal priorities for each, the process of considering and acting on each problem separately — a linear, sequential approach — only delays the final results and makes the ultimate price more expensive. This simplistic method of problem solving can be seen most obviously in city government operations, where agencies do not coordinate their plans and activities, resulting in the now-usual urban mix of counter-productive activities; one agency will pave a street, unaware of another agency's plans to dig up that street for major repairs in the near future.

If a project solution can be found that promises to meet several needs simultaneously, then the total results are more quickly achieved and this approach becomes more cost-effective. This will add more complexity to the solution, but that can be kept under control by detailed planning and clever design. As a counterweight to this complexity, there is a higher likelihood of obtaining synergistic results from simultaneously addressing multiple functions; expanding the storm barrier concept along the coast revealed the possibility of a high speed transportation pathway. Given limited resources, then, the solution that expands to solve several problems is simply a better investment.

Land-based Solution Limitations Justify Offshore Projects

In retrospect, our land-based plans, designs and actions in the past have left us with problems and unwanted residues. Perhaps things were not as well engineered as we thought; we were not responsive to the long range needs of our society. Some of the problems we face now, from past decisions and procedures, include:

- Escaping landfill leachate entering the ground water and streams, eventually making its way into the ocean. This also emits methane, not all of which is collected for reuse;
- Current landfill sites are "topping out," and adjacent states are legislating against the disposal of out-of-state wastes in their jurisdictions;
- Development activities have consumed, or bid up the value of, land sites where waste can safely — and agreeably — be stored, so costs are climbing.

New challenges face us as well. Because of the straight runs and large-radius curves required, high speed ground transportation is almost impossible to site through major coastal cities without taking much valuable real estate. And the MagLev trains would probably not be able to utilize existing tracks and tunnels.

There are activities that can only be done on land; agriculture, forestry, recreation and watershed collection are some examples. Other activities, such as mariculture, obviously must be on or near the ocean. However, most of the activities that we engage in can be done on land or on/in the ocean, at fixed or floating sites.

Land-based developments have tended to spread out over the available property and frequently neglected many details, resulting in a disorganized project that wastefully, and usually unaesthetically, treated the property. This has resulted in the under-utilization of land, or relegating it to some seemingly necessary but undesirable functions, thereby decreasing the land's value. The opposite holds for the design of ocean-going projects: the ship or platform must be designed from the outside in, resulting in all internal systems and subsystems being completely specified and assigned to their designated locations. Nothing is carelessly left outside the hull/exterior; nothing is taken aboard that has no place of its own. This simple difference is enough to qualify nautical design as better organized than typical land facility design.

Besides the activities that must be carried out on water, properly designed and environmentally safe offshore projects can be justified, therefore, if there is no available or acceptable space for a facility or function on land, to create new areas for expansion near crowded coastal cities, and to protect existing facilities and shorefront from storms. Another argument for offshore facilities can also be developed: placing facilities on an offshore island platform frees the on-shore land of this burden, allowing planning and implementation of steps to clean up the environment on land. Rather than being seen as a move offshore to leave a fouled nest, the offshore projects should be seen as "competition" for the land functions, spurring the land sites' owners and government agencies to "clean up their act" to be competitive. This will then benefit land usage and values as well.

Applicable Offshore Projects/Technologies

No attempt was made, for this paper, to list the many offshore projects that have been proposed. However, several special projects are worth mentioning because their design, large scale and innovative technologies are applicable to the BARRIER/WAY concept:

Holland's DELTA Plan Storm Surge Barrier

In response to a severe storm in 1953, that killed 1835 people and flooded 200,000 hectares of farm land when dikes and dunes were breached, the government of Holland undertook a large-scale hydraulic engineering project to insure that such an incident would not happen again. The showpiece of this project is a (storm) flood barrier, with support columns rising 12 stories above the ocean floor, that stretches five miles across the estuary of the Oosterschelde in southwestern Holland, and cost the equivalent of $4 billion dollars. This high price was due in part to the severe weather conditions that regularly limited the construction time available, and to not realizing the real economies of scale that a longer-span project would achieve.

Floating Underwater Tunnels for Norway and Italy

Plans are underway for several tunnels that would "float" at a depth of more than 100 feet (with tethers to the bottom) across water inlets in Norway and Italy. The Norwegian activity, named the "Haerkfeu" Project will span part of the Boknfjord, and connect Stavanger with the cities north of the Fjord. The Italian tunnel, known as the Archimedes Project (one of three concepts for spanning the Straits of Messina), would finally connecting Sicily to the Italian mainland. The Straight has an average width of about five kilometers.

Details of the Megabight Barrier/Way Concept

Concept Meets U.S. Coastal Area Needs

The MEGABIGHT BARRIER/WAY concept is intended to meet U.S. coastal area needs for waste disposal, storm protection and the creation of new land and pathways for a variety of uses including interstate transportation and shipment of energy and materials.

Optimization of Location for MEGABIGHT BARRIER/WAY

The final location of the BARRIER/WAY will be the optimal solution to competing needs, to maximize the revenues produced (from the largest number of functions it could perform) for repayment of the construction funds. Factors to be considered in locating the BARRIER/WAY include:

- Depth and ocean floor composition/strength along the Continental Shelf,
- Positioning of BARRIER for maximum storm protection, with minimum impedance to tidal flow under normal conditions,
- Length of roads/rail feeder lines from shore to the MAGLEV WAY,
- Aesthetic considerations; should it be seen from shore (destroying the natural view from the shore), or should it be below the horizon? This, in turn, is affected by the design approach for ship clearance; a higher structure to minimize ship accidents must then be farther out to sea, while a submerged tunnel allows the BARRIER/WAY to be closer to shore.

Designing for Multifunction Use

The BARRIER/WAY would be designed to incorporate and perform as many functions as feasible, to meet the multiple needs of the coastal areas.

Environmental Considerations & Impact

Properly designed, these offshore islands would offer safer containment for waste (solid waste and refuse/toxic waste/sewage sludge/dredging spoil) than they now get on land, and so would do less damage to the land and ocean environments. These offshore islands could also be designed to accommodate all the solid waste now in existing landfill sites, freeing these lands for sanitizing and eventually for (re)development. Thus the land environment is considerably improved.

The long term environmental impact of these islands must be considered (The short term impact of the construction must be considered also, but only if the concept appears to be feasible in the long-term.) What is the impact of the "loss" of the seabed that becomes the base of the island, and the impact of the shadowing caused by the island structure? Will there be any slippage of the seabed caused by the weight of the island and structure?

Would the installation of artificial wetlands interfere with normal fish movement and spawning patterns? Would the ocean fish find these islands? Could the wetlands function be "primed" by "salting" them with fertilized eggs? The impact of the barrier/way on migrating birds, shore birds, sea mammals, fish, shellfish and plankton, etc., must be considered.

This overall concept, properly functioning, affords protection to the ocean's environment while allowing — and stimulating — cleaning up of the coastal land environment. The island string must be designed to minimize any disruption to the tidal flows that are vital to existing wetlands and for cleansing sounds, bays and harbors.

Construction Details & Sequence

The basic island structure is envisioned to be formed by a ring of interlocking, reinforced-concrete caissons with joint seals, driven into the ocean bottom. Clean fill from land is then banked around the outside to create a hollow island that has a natural appearance. Some platform structures could be "balanced" on the edge, to support crews and equipment, etc., until the island is filled. Once filled (cell by cell), the refuse core can be capped by the clean fill, creating an area for development and use. (The solid waste material is assumed to be solidified, to prevent any unwanted settling of the surface.)

These island rings, even before filling, can be the base for linking spans, allowing transportation and equipment/material delivery between islands. This linkage could be expanded into a travel way (road/rail) and could support energy and material lines.

A string of islands, regularly spaced, can act as a diffraction grating for the incoming waves, creating wave reinforcement patterns that could be utilized for energy recovery, or at least concentrates the waves so that a dissipation device could effectively attenuate them.

The floating wetlands can (initially) be manufactured onshore and towed to the islands. Attached to the lee side of the islands, the wetlands can then be "stocked" and primed, and watched over.

Downside Considerations: Accidents / Storm Damage / Lack of Revenues

The design trade-offs regarding accidents include the height of span vs. average ship height (so that a ship out of control cannot crash into the span structure), or the depth of the tunnels to allow ship clearance overhead. The infrastructure paths, whether above or below water level, would probably be integral with the tunnel.

Regarding storm damage, the barrier would be designed to withstand the maximum forecast storms, and to protect the shoreline. Emergency shutoffs and quick disconnects could be built into the spans/tunnels and infrastructure lines in case a storm exceeds design limits, or the "impossible" ship accident occurs.

In regard to a possible shortage of revenues (to pay for the construction), the contractual arrangements for the majority of the revenues must be agreed upon before construction begins.

Project Cost & Revenue Estimates

Preliminary cost and revenue estimates must await receipt of detailed information from Holland regarding the Oosterschelde Barrier costs, and from Norway and others considering the floating tunnel concept. A preliminary design study must be undertaken then, to develop early cost estimates. The overall project design will emphasize the replication of standard elements and modular construction, thereby minimizing the cost.

Building Public Support for Offshore Projects

Ocean projects can meet several pressing needs: they can better protect the ocean environment; they can insure the continuing availability of the ocean's resources that we have come to depend on; and they can give land space a "breather" so that we can clean up existing problems. Competition with land for activities and facility space might further encourage this cleanup.

One of the largest problems facing Western civilization is the storage and disposal of its solid waste, at a time when available land for such use is becoming increasingly scarce, more expensive and legislated out-of-bounds. There are increasing demands on the existing land, and greater resistance from the public to the siting of waste disposal sites near their homes and water aquifers.

Many other demands for/against sites can no longer be economically or easily met on land. These demands can be classified into three groups:

- Facilities the public refuses to have near their homes,
- Facilities the public prefers not to have nearby,
- Sites (requiring access to the ocean) that are not available.

The ocean environment has been seriously degraded in the past, principally from nondegradeable and/or toxic substances released into the ocean. The ocean has always seemed like the perfect "source" for limitless seafood and other marine products, and an ideal "sink" for all the unwanted by-products of our civilization. Once they are disposed of in the ocean, they are expected to be either dissolved, neutralized (by the salt) or simply hidden by the opacity of the waters. The pollutants and stirred up mud adds to the opacity, increasingly covering up our transgressions.

The marine life of the oceans has been seriously depleted by overfishing, and this process is now accelerating with the gillnets. And all at a time when Earth's expanding population requires more protein.

Rather than wait for more floatables washing ashore to cause citizen outrage, steps should be taken now to enlighten the public to the need for, and great benefits from, large-scale offshore projects. Reviewing the success of past projects, and comparing them to projects planned for the future, would give the public a broader perspective on these activities. Showing the direct benefits that these projects will offer, such as jobs and local economic stimulus, will also help in focusing them on the positive side of these activities. Like it or not, our society is dependent on large projects for its survival, and that dependence is growing along with the population. This message should be developed and displayed in a central, highly visible site in the downtown areas of our major coastal cities, and even inland.

RECOMMENDATIONS FOR IMPLEMENTING OFFSHORE PROJECTS

The System Study: Expanded Perspective & Interfacing Mechanism

One characteristic of a systems problem is its overwhelming nature when first encountered. And the coastal area needs cited earlier are all elements of a multilevel systems problem that we must begin to deal with. However this confusion soon yields to the defining process of the systems approach, and theory tells us that if there is one solution to a problem, there are probably other solutions. The systems approach integrates all factors that affect the problem; we are limited only by our imagination and understanding of the situation. This systems approach procedure permits the coordination of all the interdisciplinary elements — and participants — in the study, design, simulation and implementation phases of the project, and promotes objectivity in the study effort.

The Systems Study

The first step in the recommended systems study is to understand the needs confronting the coastal areas. For the purposes of this study, these will be confined to infrastructure and service needs of the community, thereby limiting the study to considerations that could easily benefit from new approaches and technologies (and the area considered is limited as well). The consideration of these needs and the situation facing us allows the statement of central objectives, and subobjectives, which are then developed into the desired system goals, guidelines and constraints. These, in turn, are used to develop the system and subsystem performance requirements that then evolve into the evaluation criteria.

A true systems study allows for consideration of all candidate solutions to a problem, evaluating them over the full desired range of performance variables and under the environmental conditions expected. The candidate solutions must be equally and objectively evaluated using all the criteria derived. In this offshore system case, these would include pertinent sociological, ergonomic, psychological and aesthetic/philosophical criteria as a counterbalance to the traditional technical cost-effectiveness (including revenues), the total land-sea environmental impact, economic impact and implementability/manageability.

The proper multifunction systems study is conducted parametrically, examining the entire range of conditions that the candidate solutions must perform within. The analysis of alternate concepts would probably be done in two phases: initially the criteria would be applied to one size of the design for each concept, and then the priority-ordered (favorably rated) concepts would be subjected to a parametric analysis that examines the concepts' complete range of performance as their variables undergo change. In this way, the optimum size of the recommended project could be determined.

There is even a benefit in going beyond the understood conditions and ranges, to build in extra capability and to compensate for shortcomings in the original performance range estimates. This also allows for consideration of how many separate functions could be performed simultaneously by each candidate solution (or combination of solutions), leading to an understanding and evaluation of the multifunction capabilities of each. The multifunction solutions can produce additional revenues, from more services performed and facilities created, to defray the costs of the construction. In this era of government budget deficits, self-financing projects would stand a much higher chance of implementation.

In rigorously defining a system, the approach recommended here is to go beyond the system being considered, to insure that interactions at a higher level do not adversely restrict the considered solutions at the target level and so can be safely neglected. This system definition is then the basis of developing a computer model for simulation studies, and the mathematical model can be checked by using an analog physical model in a scaled testing facility (e.g., ship or platform models in a towing or wave tank).

In selecting the candidate systems for evaluation, some stimulus should be applied to insure that these solutions are "large enough." The candidate solution designers will be reminded of the extra functions that larger concepts can handle, thereby creating increased revenues, and so they will be encouraged to "think big" in the beginning. The concepts can be trimmed to their optimum size during the parametric analysis, but analytical tricks cannot expand a solution that is too small to start with.

Interfacing with Government, Financial and Legal Communities

From the earliest planning stages, the MEGABIGHT BARRIER/WAY study group would interface with the appropriate government agencies. Lacking any government funds to invest, these agencies would still be required to insure the project's compliance with the many regulations that would impact its design, construction and operation. A principle concern of the agencies would be to insure that the MEGABIGHT BARRIER/WAY concept meets its stated goals to enhance the environment. This will be a measure of the impact on both land and the ocean, taken together.

During the feasibility study phase, the study management would contact select representatives of the financial community, including commercial banks, brokerage houses, investment banks and venture capital firms, regarding the eventual financing of such a large undertaking. The intent is to explore the many ways that funding such a venture can be raised. The current emphasis of the financial community on short-term, low risk investments is noted; perhaps some special media presentation on large projects would stimulate their interest, or some new forms of investment instruments can be devised that attracts investment.

The legal and insurance communities would be invited to participate as well, to help sort out the many ownership and liability questions that such an undertaking raises.

Private Initiatives for Project Implementation/Producing Revenues

There has been a successful history of joint public-private projects in the past. Public corporations such as COMSAT and AMTRAK have functioned well, and "Authorities" function with a combination of public and private funding. Private investors and the government share in the investment and the profits. However, "There are residual suspicions that make it difficult for government and industry to cooperate fully and on a basis of mutual confidence and respect." [MACRO by Frank Davidson, p. 302]. But these problems in cooperation may be moot for the foreseeable future, as the federal government and the eastern states all struggle with massive budget deficits.

The only feasible answer, for the foreseeable future, is to structure these projects as private initiatives completely, and raise private monies to finance the projects. This becomes feasible only if the project promises to produce the revenues that would repay the construction cost.

Past projects that have utilized private funding have relied on the availability of government guarantees for the investment. It is uncertain that such guarantees will be forthcoming in the future, given the perilous financial condition of the federal government and states; as investment services continue to lower their ratings on government bonds it is difficult to see any serious, large investors (private or institutional) offering money to future projects backed only by a "moral obligation."

On the positive side, new opportunities on the international investment scene are now possible. Joint funding of the English Channel Tunnel is a reality, and there are still sources of wealth looking for a stable country to invest in. Undertaking an elaborate project such as the MEGABIGHT BARRIER/WAY would convey our confidence in the country's future, and that would attract such investors. New organizational structures may be needed to finance this size venture, but that is the sort of challenge we respond well to.

The National (U.S.) Public Works Improvement Council has calculated that a dollar of public capital invested (in transportation) leverages 10-15 times that in private business activity. Besides the stimulation to the local economy, the investment would create immediate jobs, and then long-term competitiveness.

The revenue-producing functions performed by the MEGABIGHT BARRIER/WAY include:

- Ocean and land environment improvements should be "rewarded" from general tax revenues; or from insurance companies.
- Storm surge protection could share insurance rate reductions (similar to reduced rates for nonsmokers/drinkers).
- Waste recycling and disposal sites would receive the (reduced) tipping fees, and share in the sale of sanitized landfill sites for redevelopment.
- New offshore sites for commercial and residential development could be sold or leased.
- Supporting mariculture facilities (floating wetlands) could be reimbursed from a seafood sales tax.

- New recreation areas and ocean access would generate attendance fees.
- Hazardous material (LNG) storage sites would be leased to contractor.
- Power plant and desalination plant sites would be leased/sold to utilities.
- Oceanography and mariculture training and research labs could be leased to educational institutions and companies.
- Isolation and rehabilitation community sites should be leased to local governments, or to corporations if these activities are privatized.
- Environmental research facilities would be leased to government agencies, educational institutions and/or companies.
- Airport and STOL port sites could be leased by the Authorities or corporations operating them.
- Deep water ports and naval base sites would be leased/sold to the agencies, authorities or corporations using them.
- The road and MagLev transportation way would generate tolls and passenger fees.
- The safe path for material and energy transfer (by pipe) could generate user fees.
- Leakproof bases for offshore drilling/pumping would be leased/sold to the oil/gas extraction companies.
- Wave energy recovery would provide "free" energy for the facilities; wave tripping devices could share in the insurance fees, etc.

The inclination at this early point in the concept's development is to favor leasing, rather than selling, the properties by a holding authority, which would better enable one organizational entity to implement and enforce the strict controls to insure safety and the overall improvement of the ocean environment.

The Oceaneering Texpo Center to Build Public Support

To stimulate public awareness, acceptance and support of large ocean-going projects, TRANSYSTEMS INC. proposes to create a network of OCEANEERING TECHNOLOGY EXPOSITION (TEXPO) CENTERS that will explain the necessity for such large ocean projects, the public benefits from them and how individuals can seek job/career/investment opportunities through these centers. These centers would be in the heart of major metropolitan areas that are on or near the coast; areas that would be the first affected by further degradation of the ocean environment.

The centers would appear most like a permanent World's Fair exhibit, with educational exhibits that explain the current state of the ocean, project ahead to identify special problems that will arise if we continue current utilization and disposal practices, and display plans for projects that could meet our future needs. The visibility afforded by an OCEANEERING TEXPO Center in a major metropolitan area, and the free publicity this can attract, will promote the legitimacy and public acceptance of offshore projects.

The visibility and central location of this center will enhance its educational functions. As a lab for training and research, the center improves the image of offshore engineering and attracts and motivates better students. OCEANEERING TEXPO becomes a central location for coordinating activities and projects; "one-stop-shopping" for knowledge, consultants, companies, etc., and financing assistance.

OCEANEERING TEXPO will offer a variety of functions and services to attract a wide audience, ranging from the lay public to professionals and academics. The identified audience segments include:

- Oceaneering professionals and entrepreneurs,
- The general public, tourists and tour groups (all nationalities),
- Students (all grades — elementary, secondary, vocational and trade, undergraduate and graduate, and continuing ed; subjects including science, biology, environment systems, engineering and technology, business and finance, law, and some liberal arts),
- Academic faculties (all levels),
- Researchers (e.g., scientific, technical, sociological and finance/business),
- Oceaneering-employed adults being retrained,
- Non-oceaneering adults being broadened/reeducated,
- Government employees, administrators and legislators,
- Oceaneering and corporation executives,
- Non-oceaneering executives.

The OCEANEERING TEXPO Flagship Site in Rockefeller Center

The intention is to offer highly visible demonstrations and examples of the newest offshore projects, equipment and procedures, for government, industry, academia and the public. As such it demands a central, easily accessible and highly visible location.

One of the sites that has become available for the OCEANEERING TEXPO Flagship is at 1221 Avenue of the Americas, between 48th and 49th streets; the former Irving Trust bank space at street level, plus lower levels, in the McGraw-Hill Building in Rockefeller Center. The site contains six levels which enclose over 40,000 square feet of space, plus additional display areas in the spacious hallways.

Other Candidate Cities: The OCEANEERING TEXPO Network

The major coastal cities around the country would be candidates for such centers, to be linked into a network by telecommunications. The candidate cities include:

- Boston
- Norfolk
- Tampa/St. Petersburg
- Brownsville
- San Francisco
- Annapolis
- Jacksonville
- New Orleans
- San Diego
- Seattle

and such exhibit centers could be welcomed at major inland cities as well.

Center Exhibits and Equipment

The showpieces of the OCEANEERING TEXPO exhibit would be models of actual and proposed oceaneering offshore projects that demonstrate their functioning and environmental protection. These models could be in working wave tanks, etc., showing the actual testing of a conceptual design. Models and/or full sized pieces of the unique equipment used in offshore projects could be on display, and could even be working exhibits. Remotely-controlled underwater robots could be shown in operation.

Media presentations, using film footage from actual operations, could be combined with CAD computer graphics to illustrate and animate the concepts. An interesting possibility to pursue: develop Virtual Reality exhibits that create an underwater environment or part of a proposed project, that the viewer can "enter" via the goggles and glove, etc. These can also simulate the remote operation of the robotic devices through "hands-on" controls.

The Participants

Participating organizations and individuals include:

- Government agencies and labs,
- Corporations manufacturing offshore/underwater systems and equipment,
- Universities and labs / private labs,
- Consulting firms and individuals.

Media Presentations

Multimedia productions at this center would develop a positive message about large-scale offshore projects. Elements of this message could include:

"Oceans are a major element of the world's environment and biosphere, and provide us with a substantial part of our (food) resources."

"Oceans have been degraded by pollution and dumping, etc., putting the environment and the continuous supply of seafood at risk."

"New projects can clean up much of the past pollution — and prevent virtually any more in the future — allowing the oceans and the environment to recover."

"Offshore projects can provide sites for facilities that are not desired on land, or cannot possibly be done on land."

"Big projects will be needed to cope with the Big Problems we face; 'Band-aids won't work anymore!' "

"There is an opportunity for you in this project/technology, and we want to help you seek it out."

The Operation of the OCEANEERING TEXPO Centers

A combination of full-length (45 min.) and brief (3-5 min.) multimedia productions would run at periodic intervals (tied to the tour cycle) to explain the need for, and purpose of, offshore projects to the general public; special productions could also be developed for professional audiences, etc. The center would feature exhibits showing models of offshore projects (possibly actually being tested in a wave tank) and some of the actual equipment used in underwater work.

A key ingredient, for building public attendance and support, is to create a "High Touch" environment at the center; space where the public can congregate with others of similar interest after the tour and multimedia show, learn the latest information on the proposed projects, register themselves to receive information on how they (individually) can participate or share in these activities (jobs, career changes, high tech underpinning courses to improve their capability and understanding, upcoming activities of interest, investment opportunities, etc.), have some good quality food and drink, and attend the live entertainments offered, plus be able to sign up for activities and tours that will be outside the center.

The OCEANEERING TEXPO Center's Revitalizing Functions

By designing it from the start to be a compatible, multipurpose center, the following functions can be incorporated to simultaneously operate in this one facility.

• Demonstrating offshore projects, systems, equipments, processes and technologies, through models, testing tanks, simulation programs and media presentations, to visiting representatives of government and industry, students and the general public (tours),

• Consulting to companies interested in offshore activities, or in supplying the construction effort, as systems integrators, and offering turn-key modernization services,

• Marketing tools, equipment and systems to companies, and merchandising tools and technical products,

• Acting as an integrated systems "BIG LAB" for local schools and colleges (until the offshore labs are ready), in the training of all levels, from technicians to professionals and managers; inspiring students' career decisions; retraining adults,

• Providing a "springboard" for entrepreneurs to enter the offshore business arena,

• Designing new systems, products and components for corporate and/or entrepreneur clients,

• Providing information to small companies and entrepreneurs to help them with their technical problems (Knowledge Infusion),

• Utilizing the TEXPO facility for faculty and graduate student research,

• Speeding the development process, to accelerate the application of new research results to practical products,

• Identifying projects and businesses overseas, that could utilize local (U.S.) companies with certain capabilities (if they arecompetitive),

• Arranging financial assistance for offshore companies,

• Enlightening the public about the challenges and opportunities resulting from these projects and new technologies, and offering them a self-help data base,

• Educating executives and managers (High Technology Underpinning); and developing and offering a Job Bank data base at all levels for this employment area,

• Evolving into the Flagship for a Network of Centers — first in oceaneering, and later integrating into multiplexed networks that combine all technologies,

• Dramatically improving the image of offshore projects and large systems activities, and the revenues produced by the performance of these functions make the center self-supporting.

(Edited by P.M. Grifman)

Port Development and Marine Transportation

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How Do You Describe a Containerport?

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ABSTRACT

Containerports represent an important use to be considered in coastal ocean space utilization. An obvious issue is how should a containerport be described so that coastal zone planners have all the information they need.

This paper describes the following three approaches: (1) Physical (2) Traffic, and (3) Market. A physical description includes the dimensions of the channel leading to the terminal, the size of the docks and terminal areas and, the various pieces of equipment in the facility. A traffic-oriented description includes the amount of cargos and containers moving through the terminal. In addition, a pattern of traffic flows is part of this description.

A market description deals with the competitive position of the port. Although such a description is not as precise as the other two categories, it has the advantage of giving some insight into possible future port activities and resulting impacts on coastal ocean space utilization. Within the market description category, two possible approaches are discussed. The first is a determination of whether the port is a load center port. The second deals with three different tiers or layers of ports.

An understanding of all the different types of descriptions will result in planners asking for and receiving the most appropriate containerport descriptions to meet their individual needs.

International Perspectives on Coastal Ocean Space Utilization
Phyllis M. Grifman and James A. Fawcett, Editors

INTRODUCTION

Anyone dealing with coastal ocean space utilization will encounter containerports which occupy huge amounts of prime waterfront property. The way a containerport is described will help or hinder a planner in his or her activities.

This paper deals with the many different ways in which a containerport can be described. While the exact types of information desired will depend on the activity involved, it is valuable to understand the options available.

APPROACHES

This paper describes three different approaches to thinking about data needs: (1) Physical, (2) Traffic and (3) Market. Each of these approaches is described.

Physical

A description of the physical properties of a containerport is useful in understanding the coastal space being utilized as well as the potential uses of the facility. An industry reference book, such as *Guide to Port Entry*, will provide the following types of data for a containerport:

Channel depth and width
Maximum size of vessel
Number of container handling facilities
Length of each berth
Depth alongside each berth
Size of each facility
Types of shorebased equipment
Number of gates
Description of building
Description of container storage space
Description of chassis storage space

The above information provides an overview of the amount of space utilized in the coastal zone by each containerport. The data will be important to a coastal zone planner who is looking at different sites for alternative uses in the coastal zone.

In addition, this information can also be used to calculate the theoretical throughput capacity of each facility. The "Port Handbook for Estimating Marine Terminal Cargo Capability" provides graphs for turning input parameters such as berth length, yard storage area, and other factors into annual cargo throughput.

Traffic

Another way to view the port is to look at what actually moves through the facilities. Table 1 shows the amount of container traffic in U.S. ports in 1989 measured in metric tons as well as twenty-foot equivalent units (TEU). A forty-foot container would be represented as 2 TEUs. Information could also be provided by the port authority (or trade journals) on frequency of ship arrivals as well as possibly truck and rail traffic. Data on traffic flow by each mode will provide a planner with some insight into the environmental impact of transportation vehicles at the containerport.

Market

Still another way to look at containerports is in terms of their market positions, in other words, where they stand competitively. There are two approaches to defining market position. The first approach has only two classifications: loadcenter ports and other. This way of viewing containerports is a reflection of predictions made during the early years of international containerization. At that time it appeared to some that breakbulk cargo ships serving between 8 and 20 ports per round trip would be replaced by containerships serving only one or two major ports per continent (with the remaining ports served by feeder ships or inland transportation). Consequently, the small number of huge ports remaining would be the loadcenters. In theory, a look at cargo volume would easily show which ports were loadcenters.

However, the reduction in number of port calls has not been as great as predicted. This result is more consistent with the second approach that views containerports and containership operators in three tiers, in accordance with competitive strategies as explained by Michael Porter. It is helpful to think of the three categories or tiers as large (for the first tier), medium (for the second tier), and small (for the third tier). Market share on the trade route being considered may be a better measure than the absolute size of the firm. Further reflection reveals the three tiers to have a relationship between the strategy and technology chosen. In general there will be a tendency for carriers and ports of the same tier to deal with each other.

Table 1
U.S. Port Container Traffic 1989
(TEUs/Metric Tons, Except Where Noted)

Port	TEUs	Metric Tons
Anchorage	256,078	1,153,235
Baltimore	569,000(b)	3,874,824,
Boston	140,039	917,021
Charleston	795,385	5,619,699
Chicago	542	n I a
Cleveland	245	1,958
Corpus Christi	158	n/a
Detroit	642	n/a
Fernandia	35,818(c)	315,389
Freeport	27,898	158,128
Galveston	66,928	459,364
Gloucester City	68,450	565,667
Guam(fy)	104,495	1,131,786(rt)
Gulfport	nfa	518,337
Hampton Roads	685,295	4,897,358
Hilo(fy)	29,882	332,914
Honolulu(fy)	375,876	3,991,201
Houston	492,158	3,607,844
Jacksonville(fy)	126,319(c)	1,752,638
Kahlului(fy)	38,952	424,295
Kanakakai(fy)	600	7,152
Kawaihae(fy)	10,461	113,903
Long Beach	1,575,117	28,587,312(mrt)
Longview	3,039	n/a
Los Angeles	2,056,980	n/a
Manatee	4,500	25,020
Miami(fy)	337,961	1,916,613(b)
Milwaukee(a)	92	1,261
Mobile	15,452(c)	135,536
Nawiliwili(fy)	14,395	157,579
New Orleans	179,874(c)	n/a
New York/New Jersey	2,000,000	12,000,000
Oakland	1,069,250	12,674,965(mrt)
Palm Beach(fy)	121,137	849,730
Philadelphia	80,674	n/a
Port Everglades	235,865	1,324,661
Portland(OR)	186,027	1,707,022
Portsmouth(NH)	2,266	61,621
Richmond(VA)	26,001	218,110
San Diego(fy)	7,867	73,078
San Francisco	117,597	2,562,329(mrt)
San Juan	1,312,000	5,600,000
Savannah	376,295	2,758,506
Seattle	1,041,000	7,744,000

(Continued)

Table 1 (continued)

Port	TEUs	Metric Tons
Tacoma	924,974	6,031,074
Tampa(fy)	4,459	36,522
Vancouver(WA)	402	9,489
Wilmington(DE)(fy)	78,284	408,108
Wilmington(NC)	99,031	607,758

ABBREVIATIONS

fy = fiscal year mrt = metric revenue ton rt = revenue ton

TEU = Twenty Foot Equivalent Unit

NOTES:

(a) Containers handled to and from vessels only. Excludes containers handled solely at rail-truck transfer facilities located on port property.

(b) Estimated by port.

(c) Container units of varying lengths, not TEUs.

Data are for calendar year except where noted. Data reported in short tons were converted by AAPA to metric tons at 1 short ton=.9078 metric ton. Reported figures count domestic and military as well as export/import traffic.

Source: AAPA telephone survey and statistical reports furnished by ports.

THREE TIERS OF CARRIERS

First Tier Carrier

A first tier carrier is one that can differentiate itself from the others on the basis of cost or quality of service. In theory, a carrier would like to have the lowest cost and the highest level of service. However, it is very difficult to exhibit both characteristics at the same time.

It is also difficult to succeed by having low cost while having a poor level of service. This combination of characteristics was one of the problems faced by U.S. Lines, a firm that went bankrupt. U.S. Lines had large, slow, economical ships. Carriers with faster ships and double-stack container trains were able to attract a higher-value cargo, which meant higher-revenue cargo. Another problem is that the price seen by a shipper may have little or no relationship to cost in the short run. In other words, the carrier with the lowest costs may not have the lowest prices because competitive pressures keep the competitive rates down.

The above discussion demonstrates that the most successful first tier carriers are the ones that differentiate themselves on the basis of quality of service. Shippers tend to measure service in terms of origin-to destination transit time, reliability, loss and damage, ease of documentation, and container tracing. What type of technology is needed for a first tier carrier to provide a high level of service?

Keeping in mind that high quality service depends not only on technology but also on the way such technology is managed, let us consider one particular first tier, American President Lines (APL), which is part of American President Companies (APC). This carrier has huge, new ultra-panamax (i.e., too wide to fit through the Panama Canal) container ships, serving modern container terminals under exclusive lease, being managed by an APC stevedoring firm. Double-stack container railcars owned by an APC intermodal firm run on carefully scheduled trains, meet the ships at U.S. ports, and carry the containers east, where they are delivered by an APC-subsidiary trucking company. APC also owns tens of thousands of containers that vary in dimensions (up to 53 feet in length, 9.5 feet in height, and 8.5 feet in width) and in speciality purpose (such as with hanging racks for clothes and refrigerated units) and chassis. APC also provides warehousing and distribution services, owns the largest shipper agent (to arrange rail services) in the United States, has a worldwide computer network, and has started an automatic equipment identification activity, placing machine-readable tags on its equipment, thereby aiding its tracking.

The financial and managerial resources of first tier carriers, such as APL, are enormous. First tier carriers will generally serve first tier ports. In contrast, consider the other extreme, the third tier carrier.

Third Tier Carrier

The successful third tier carrier is a market niche player. Although the segment of the market is typically small, the third tier carrier possesses any one (or more) of a number of characteristics that gives it a competitive advantage in this market niche. For example, a carrier flying its national flag may have special access to certain government-related cargos. U.S. carriers like *Rainbow* count on U.S. military cargo for their survival.

Other competitive features include focusing on a particular type of cargo or a certain shipper; having a unique type of ship either in terms of physical parameters or cargo-handling characteristics; serving a unique type of port facility or a remote geographical location; and having a particular relationship with the port labor force. *Senator* started out as a third tier carrier serving nonunion (or at least non-International Longshoremen's Association) U.S. ports. Independent Container Line uses small, shallow-draft vessels to serve the upriver port of Richmond, Virginia.

In contrast to the resources of a first tier carrier, a third tier carrier may lease its ships (which formerly belonged to another carrier that replaced them with newer vessels or went bankrupt) as well as its containers, and typically uses a common-user port facility, provides no inland services, and has no computer tracking activities for its shippers. Whereas the strategy-technology interrelationship is quite different from the first tier carrier, both tiers successfully combine technology and strategy to obtain a competitive advantage in their targeted market.

Second Tier Carrier

The second tier is made up of all the remaining carriers. In terms of numbers of carriers, this tier is probably the largest on any given trade route. Although these liner operators are larger and possess more resources and services than the third tier carriers, they lack the market focus and competitive advantage of the third tier firms. On the other hand, the second tier carriers are lacking in both resources and services when compared with the first tier companies. Consequently, the second tier firms are more vulnerable than either of the other two tiers and depend on the basic supply-demand relationship in the market for their profitability and survival.

THE PORT'S MARKET POSITION

Defining a Port's Market Position

Figures 1, 2, and 3 provide a graphical representation of cargo flow through U.S. ports shown in order of decreasing throughput from left to right for 1979, 1984, and 1989, respectively. The data are taken from the *Containerization Yearbooks* and Figure 3 is consistent with the data in Table 1. The procedure to classify the ports clearly as either loadcenters or as first, second and third tiers is not a trivial one. Due to the huge range of volume through U.S. ports, it is obvious that the left hand side of the graph contains the first tier ports or loadcenters while the extreme right hand side contains the third tier ports. However, the breakpoint between the first and second tiers as well as the second and third tiers is not easy to determine. In fact, over the eleven year period shown, the tops of the bars in the graphs of the decreasing volumes seem to create a smoother curve over time.

While there may be many reasons for the relative smoothness of the curve of decreasing cargo volumes, one cause appears to be that there is not always a consistent match between the tier of the carrier and the port. In particular, it seems that some first and third tier carriers use second tier ports. (One might also argue that the differentiation among one, second, and third tier carriers is not obvious.)

Although the author cannot provide a foolproof method for classifying ports by tier (or defining the minimum throughport of a loadcenter), in many cases the position of the containerport on Figure 3 will provide a relatively clear indication of its market position. Such a classification may be helpful to the planner in providing insight as to the port's future impact on the coastal zone. In some cases a more detailed analysis of the port's competitive strategy may prove useful.

Impact on Coastal Space Utilization

An advantage to describing containerports by their market positions is that such a classification may provide insight as to the port's future impact on coastal space utilization. For example, ports focusing on third tier carriers should not encounter problems with the public. Typically, such a port, which would normally be a third tier port, is underutilized. The specialized facility needed by the carrier generally results in local benefits that are easy to recognize and support.

The port that attracts a first tier carrier will have to provide extensive facilities; however, this investment will result in significant benefits. Because of the financial resources of the first tier carrier, the port, generally a first tier port, will typically be taking little financial risk. On the other hand, the public may not like the distribution of costs and benefits. In fact, as the port becomes more successful, the local taxpayers may become more concerned with resulting by-products such as traffic congestion and pollution.

The port focusing on second tier carriers may face the widest range of public reactions. The second tier port is faced with the widest range of choices and the carriers may have limited financial strength. Consequently, the port may find itself having to justify why it did not take alternative actions and why it appears to be taking high financial risks.

CONCLUDING COMMENTS

This paper has described three different approaches to describing containerports. An understanding of all the different types of descriptions will result in coastal zone planners asking for and receiving the most appropriate containerport descriptions to meet their individual needs.

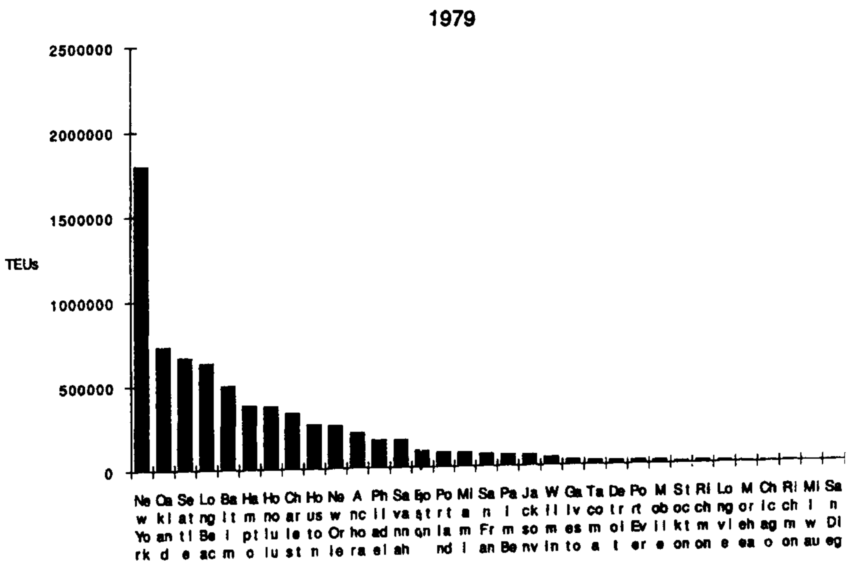

Figure 1. Container Traffic Through U.S. Ports in 1979 (increased in TEU)

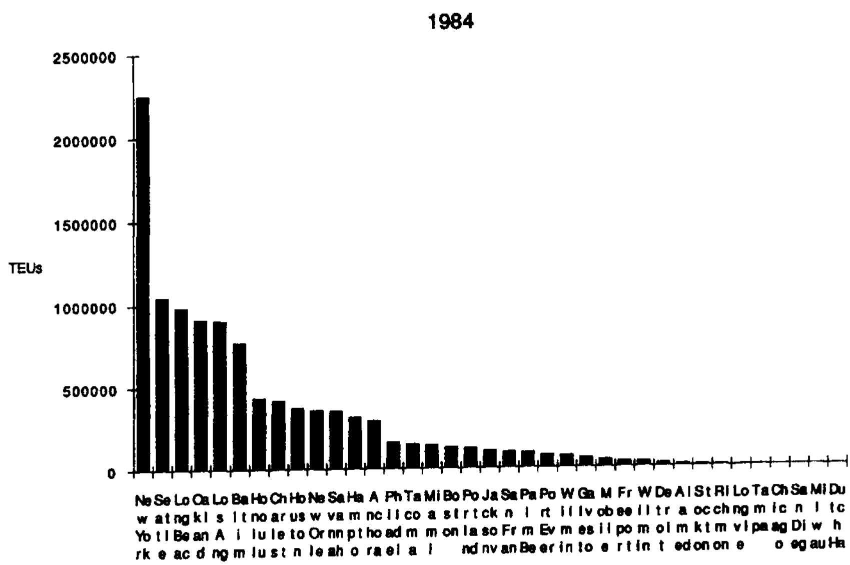

Figure 2. Container Traffic Through U.S. Ports in 1984 (increased in TEU)

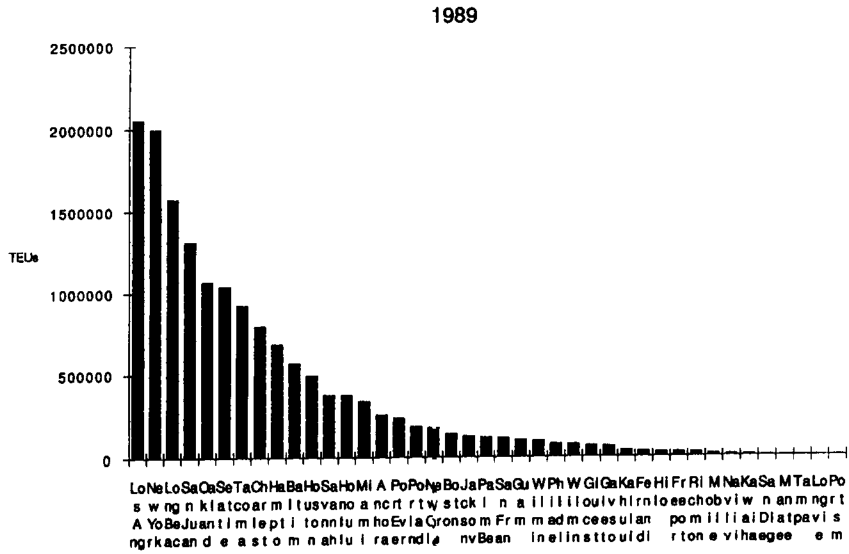

Figure 3. Container Traffic Through U.S. Ports in 1989 (increased in TEU)

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Overcapacity in Port Container Terminals: Planning Techniques and Policy Implications for Port Managers and Public Officials

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ABSTRACT

This paper explores the issue of overcapacity in port container terminal facilities. The problem with overcapacity is that it represents an inefficient utilization of coastal lands, public funds, and implies unnecessary environmental degradation associated with dredge and fill activities. Unfortunately, the development activity of politically autonomous state port authorities rarely meets the expectations of public accountability towards the efficient use of coastal ocean space at both regional and local levels.

Presently, there is no federal policy and little state initiative aimed at the management of port overcapacity. This paper examines the issue of overcapacity and mechanisms at the federal, state, and regional levels which can manage overcapacity. It also explores the questions surrounding the management of public port enterprises as private corporations. Finally, it looks at methods of assessing overcapacity and how these planning tools could be utilized.

INTRODUCTION

The advent of containerization and intermodality has altered the conventional structure and dynamics of port competition in the U.S. and around the world. In addition, the emergence of a global economy is spurring increasing inter-port competition for containerized cargo. The dynamics of the intermodal concept have

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shifted port competition to the inter-regional level.[1] This has led to extensive investment in specialized container facilities.

The pressure of competition has fostered a development process resulting in the overcapacity of port container facilities. Since the 1970s, there have been charges that ports were exhibiting overcapacity and that unnecessary facility duplication would represent an inefficient use of public funds, coastal space, and result in environmental degradation.[2] This overcapacity is likely to increase as the pressures of intermodalism and an expanding global economy take hold. While some excess capacity is a natural and desirable condition of the system, wasteful overcapacity in container facilities may not be desirable from a public perspective.

Extreme overcapacity in a port range is symptomatic of poor planning and inefficient use of coastal open space. This inefficient use directly affects the public in three ways. One, land is lost to other water dependent and public uses. Two, it represents the suboptimal allocation of coastal ocean space and public funds. Three, it suggests long-term environmental effects upon the marine and coastal environment associated with port operations.

The problem of overcapacity in container facilities is a direct result of the economic system in which ports operate. Although competition leads to overcapacity, it most likely is the most efficient system available to the U.S. port industry. The autonomous and highly competitive port industry attempts to remain market efficient by offering high quality services at fair market prices, similar to other industries. Yet, at the same time, ports can be viewed as a public utility. Indeed, many are publicly owned and operated. This raises questions pertaining to the use of coastal lands and public funds for the construction of redundant container facilities. While competition will surely press for continued port growth at both public and environmental expense, public policy solutions must be formulated in order to minimize port overcapacity.

Should ports be allowed to plan for expansion apart from political review? On a state level, ports have been given the authority to do so. Port charters require only that they operate within the margins of improving local economies and increasing cargo throughput. Apart from the permitting process, development is not usually questioned. However, as public agencies, is port autonomy consistent with the requirements of public accountability? Since the port system is competitive, expertise is required for port management and minimum political control is required if the port is to compete freely. However, to what extent should ports such as Long Beach continue to expand if the local benefits of incremental expansion are decreasing while placing additional stress on community infrastructure and reducing the availability of coastal land?

This paper explores the issue of overcapacity from a public welfare perspective. It will focus on the factors which influence overcapacity as well as the impacts of this resulting overcapacity. This paper will examine the question of managing public port entities as private corporations and assess the extent that port autonomy is consistent with public accountability. The role of federal and state governments with respect to managing port overcapacity will be addressed. In addition, this paper will suggest methods to improve management of port capacity at the state and regional levels. This will include methods of measuring and estimating port overcapacity.

OVERCAPACITY OF PORT CONTAINER FACILITIES

There is no concrete definition of excess overcapacity nor is there a definition of what constitutes a desirable level of overcapacity. Generally, excess capacity which exceeds the requirements for peak trade spill-over and military berthing can be regarded as overcapacity. However, differing political perspectives complicate the determination of a desirable level of excess capacity. It is important to understand these different political perspectives, for it illustrates the complexity of managing the port industry.

Defining Excess Port Overcapacity

From a federal viewpoint, a certain level of overcapacity is desirable. Historically, federal port policy has been linked to transportation and national defense policies.[3] There is a strong federal interest in minimizing transportation costs to shippers as well as providing an excess in capacity to serve national defense interests in times of war. There is also a desirability to have excess capacity within a region in case of unexpected port shutdowns that could be due to labor strikes or facility damage. There is a federal interest in efficient levels of overcapacity to prevent unnecessary environmental damage.

The state perspective and that of the individual ports is quite different. Individual ports are interested in sufficient excess to ensure effective operations and allow for peak trade periods. According to the National Research Council (NRC), excess capacity is a desirable condition which allows a port to remain competitive.[4] This does not mean that the federal and state perceptions of optimal overcapacity are the same. Individual ports seek to maintain just the required level of excess capacity that is needed to attract additional market share and increase revenues.

The public concerns involving available coastal space and public expenditure influence perception such that any excess is too much. Public concerns for environmental protection and preservation often conflict with port desires to expand and upgrade facilities. It should be understood that determining the amount of acceptable excess depends upon a particular policy setting. Because the level at which excess capacity is reached depends upon a combination of these three perspectives, management for the prevention of excess capacity should naturally involve these political actors. Unfortunately, the present system of port development leaves this determination to individual ports through the results of their collective actions. What has resulted is excess port overcapacity across various port ranges. The question remains, how much excess should be tolerated by the public when this excess represents inefficiencies in public expenditure, and coastal land use?

Containerization and Port Development

During the 1950s, containers were introduced in the shipping industry and a technology revolution began which has pervaded all areas of the transportation and trade industry. The unitization of cargo has provided for faster transport into and out of ports. The container unit can be loaded directly onto truck chassis or rail cars, resulting in greater transport efficiency. Reduced pilferage and cargo damage are other advantages of containerized cargo. Since its introduction, containerization has grown immensely and has led to the development of many container terminals throughout the U.S. Ports are continually developing these terminals in an effort to increase cargo handling and revenue generating potential.[5] Consequently, the cargo-handling demands that containerization places on the port system in a competitive market have resulted in excess capacity as ports continue to expand their container handling capabilities.[6]

The unitized nature of container cargo encourages improvements in transport efficiency through technology development. In the shipping industry, new generation container vessels are able to carry 5000 containers at one time. These newer vessels require at least 1000 feet of berth space and 35-40 foot channel depths. In addition, large container vessels require fast unloading and loading capability to reduce the costly time spent in port. One large vessel can carry as much cargo as four smaller vessels, thus achieving better economies of scale. In order to accommodate these vessels and attract cargo, ports must improve their cargo-handling capability in relation to others in the industry.

The competitive structure in which ports operate continually places pressure on them to expand and to adopt new technologies in cargo handling. The growth of intermodalism and its improvements in transportation efficiency is yet another area that ports attempt to compete. Not only are they concerned with servicing their states and regions, but through intermodalism, ports attempt to service the entire country.[7] Intermodalism serves to intensify the level of port competition. Thus, the trend in the port industry is to provide large, high-technology container terminals with deep berths and plenty of acreage for storage. Competition has resulted in an attitude among ports that the bigger terminal is better.[8] Modern container terminals are designed to accommodate large container vessels and offer the highest technology in cargo transfer available. Similarities in infrastructure and superstructure across port regions pressures ports to provide better and more efficient terminals in order to maintain and improve market share. Differentiation among ports is related to the capacity of facilities to provide service at the lowest possible cost. If a shipper or carrier knows that an individual port has sufficient terminal space to immediately allocate a berth to that vessel and service it quickly, that port may have an advantage over its competitors. Ports always strive to be in this position by providing sufficient, and even excess, capacity for peak periods of trade.

As a result of this competition, development is continually occurring in U.S. ports. This development involves large sums of money for capital financing and large amounts of coastal land. Often, land is created through dredge and fill activity, or destroyed, in the case of wetlands development. The public may be unaware that most of this development is a result of anticipated, not proven, cargo growth. According to the United States Maritime Administration, "some of the port capacity being built today stems from the strong desire to entice carriers to divert cargo from another competing port rather then to serve incremental growth in cargo."[9] As public officials, these managers can acquire the land and funds they need to develop port facilities with little difficulty. Port managers often argue that the freedom to make decisions apart from political review is required for the proper management of these port entities. However, the combination of political autonomy and competition among state ports is the cause of overcapacity. Accordingly, this overcapacity implies a number of public policy issues, including wasteful use of coastal land and thus demands political attention.

Managing Port Overcapacity

The management of coastal space is becoming increasingly important as the demand for coastal land increases. Public policy which addresses coastal issues in an integrated fashion is required for the proper preservation and protection of the environment in the future. Since ports require large amounts of coastal space to operate effectively, it is necessary that port requirements be quantified through productivity monitoring and capacity review. In this respect, port development can be justified. This justified development should be incorporated into integrated mechanisms for the management of the environment and expenditure of public funds.

Environmentally, port development results in degradation associated with dredging and filling. Ecosystems are lost and disturbed by development activity. In addition, vessel traffic contributes to negative environmental degradation by water and air pollution. This pollution places additional stress on natural ecosystems. The negative consequences associated with port development imply that port managers in cooperation with public officials, should utilize planning techniques designed to limit port overcapacity.

A container capacity review can provide information to port managers and public authorities about the development needs of a port. Capacity review can be used to indicate how much excess capacity is justified. Accordingly, "the more productive you are, the more capacity can be generated in your terminals, and the less you need to expand them."[10] Capacity review models, both simple and complex, can be very useful in determining expansion needs and productivity improvements.

Measuring Container Capacity

Industry pressures for improved productivity at container terminals has stimulated ports to take a serious look at improving terminal productivity. In response to this demand, there has been considerable interest in the manner by which container terminal productivity can be measured.[11] In order for quality production in container terminals to exist, accurate quantification and monitoring is necessary. This measurement gives ports a better understanding of their capacity needs as well as productivity strengths and weaknesses. Productivity analysis and monitoring also serves as a valuable planning tool, not only for ports, but for society. It is a means to achieve more efficient coastal land-use.

A container terminal involves the interaction of port users and port facilities. The operation and level of efficiency in a terminal depends upon the productivity of berths, cranes, container yards, gates and labor. Included below is a sample of how productivity and capacity in container terminals can be measured. These measurements have been outlined and suggested as a result of the National Research Council's 1986 Study addressing the improvement of productivity in U.S. container terminals.

Productivity Factors Which Affect Container Terminal Operations

The Container Berth represents the focal point of terminal productivity. The factors which influence berth productivity include length of berth, number of cranes, berth occupancy, and cargo movement operations to and from the berth. In order to measure berth productivity a manager must take into account the number of container vessels worked per year on a particular berth. This factor represents net-berth occupancy or utilization.

The Container Yard together with the berth are the two areas in which most investment occurs. Efficient productivity management, therefore, must be concentrated in these two areas. The factors which influence yard productivity include storage acres, shape of land area, type of storage system (chassis or stacked), dwell time, and roadway design. Productivity in the yard is measured by TEUs per year per gross acre and TEU capacity per net storage acre. This yields the productivity factor, yard throughput and yard storage.

The Crane characteristics including weight capacity, single or double lift potential, breakdowns and vessel characteristics influence its productivity. Normally, cranes operate at a rate of 20-35 TEUs per hour. Double lift cranes can achieve 50 lifts per hour. However, varying rates are a function of the operators skill. Operational delays and downtime also influence overall productivity. Crane productivity is measured by moves per hour, downtime and crane hours. This measurement yields net and gross productivity.

The Gate is an important element of terminal productivity. The factors which affect gate productivity include operational hours, number of lanes, extent to which it is automated, and whether a data collection system exists. Better productivity in the gate depends largely upon the efficiency in container weighing and documentation checks. The productivity measures of the gate are containers per hour per lane and truck turnaround time. This yields net and gross throughput factors.

Labor is the final major element affecting terminal productivity. The gang sizes, work rules, general skill of workers, work environment, amount of training and vessel characteristics all influence labor productivity. This productivity is measured by the number of moves per man hour.

The measurement of terminal productivity is a valuable tool in the management of terminal operations. By measuring different productivities rather than attempting to arrive at one overall measure, a port can better manage its overall operation and make better use of its facilities. One important consideration of productivity measurement that should be made by ports and other public officials is that comparing port productivities is not advisable. Each port measures its productivity in a different manner. "This lack of uniformity...makes it very difficult validly to compare productivity data of one terminal to that of another terminal or to establish any valid standards...for international, national, regional, or portwide application."[12] Thus, any capacity review should not compare port productivities. Capacity review should look at each port separately and assess their individual requirements for expansion.

PUBLIC PORT ENTITIES MANAGED AS A PRIVATE CORPORATIONS

To what extent publicly owned port facilities are accountable to the public and the influence that this accountability should bear on the management of port operations is a central question of this paper.

Most ports in the U.S. with the exclusion of military ports are publicly owned. The most common form of public port is the port authority. Public port authorities are created by statute as non-profit organizations with a separate legal personality, the right to hold property, make contracts, adopt budgets, employ its own personal and function with considerable financial and political autonomy. The Port of New York Authority is described as:

> a public corporation set up outside the regular framework of federal, state, or local government, and freed from the procedures or restrictions of routine government operations, in order that it may bring the best techniques of private management to the operation of a self supporting or revenue producing public enterprise.[13]

Port authorities can vary in geographic scope from local cities to entire state jurisdictions. Often, the autonomous public agency is viewed with apprehension. Its actions may conflict with broader public goals such as environmental protection and coastal management.

The following discussion pertains to publicly owned and operated ports and makes no distinction based upon the jurisdictional scope of the port. Instead, this paper makes the argument that these publicly owned ports have a prevailing public interest. Accordingly, there should be some public accountability for their actions.

The Conflict Between Business Decisions and Public Interests

Public ports are quite often viewed by local communities as an important utility. They serve as a focal point for business in the port city and have a strong economic and social impact on the surrounding community.

The management of public ports as private enterprises subjects them to the demands of the competitive market system. Ports are highly concerned with their return on investment, the realization of profits, and increased market share. Since the port industry in the U.S. is managed as a competitive market oriented system, individual ports attempt to gain certain advantages over their competitors. Thus, ports attempt to offer efficient, quality service that will expedite the loading and off-loading of vessels. The problem which arises occurs when a competing port provides at least as much container handling capability as neighboring ports. The growing intermodal system of transportation is further broadening this competition as ports compete for cargo destined thousands of miles from the port of entry.[14]

While the port industry operates within a competitive market oriented system, it is also a public entity and as such, is subject to public accountability. It is often public financing which allows for port expansion and improvements to infrastructure. At the same time, the public is concerned about the impacts of the port facility on the surrounding communities. While these impacts may be beneficial such as the economic expansion within a port region, it may also have negative consequences such as those mentioned with respect to overcapacity. In many respects, ports can be viewed as a public utility.[15]

A prominent characteristic of public utilities is that they operate at their greatest efficiency as monopolies because economies of scale result in decreasing unit costs with respect to increased output. The capital intensive nature of the present port industry mandates that the more traffic moving through a port, the lower the cost per ton. From a national or regional standpoint, duplication of facilities that serve essentially the same region reduces the economic efficiency possible from economies of scale. This is particularly evident in harbors with competing ports such as the Ports of Long Beach and Los Angeles, and states such as California and Washington that have more than one port competing for cargo within state boundaries. Ports do not operate as monopolies. Instead, they operate under a more competitive market structure which negates the economic advantages attributed to economies of scale.

The negation of the economies of scale argument is particularly important with respect to public accountability. Having ports within the same state competing against one another reduces the economies of scale and results in inefficient government expenditure and higher per unit costs. Other costs to the public include the opportunity costs of the land utilized in the construction of unnecessary facilities. It also results in the public employment of duplicative personal and services that could be more productive if employed elsewhere. These all represent the inefficient use of public funds.

From a national and regional standpoint, this higher-than-needed per unit cost is undesirable because it is passed on to the shipper and results in elevated shipping costs. This has the effect of economically prohibiting some potential cargo from utilizing the U.S. port system. The federal government also has an interest in the economic vitality of the port industry, for it gains indirect revenue from port economic activity.[16]

There is an additional layer of complexity which surrounds the issue of managing public port entities as private corporations. State governments, local communities, and port authorities are concerned with the economic vitality of a port within the industry. This has led to the present competitive system. At the same time there is an overriding public interest typically administered by federal and state governments with respect to efficient coastal management and environmental protection. In other words, there is a conflict between economic motivations and environmental concerns. Yet at the present time, there is little that coordinates these actions. While there is a desire at the federal level to ensure the protection and conservation of the nation's coastal zone, the environmental permitting process isn't tied into any regional evaluation of industry requirements for growth. Interstate port competition not only reduces the economies of scale but also ensures additional and unwarranted environmental effects.

While increased container handling ability may bring positive economic benefits to the surrounding port community, there are also detrimental effects associated with this construction. These include the loss of coastal ocean space to construction facilities and increased pressure on the highway and rail infrastructure.

There are also questions surrounding continued construction of container terminal facilities. Many ports are continuing to construct facilities to service increased intermodalism. Much of the capacity that some ports are building represents cargo that is not bound for the port's region. While the port entity and the public realize a profit, impacts are also felt. In other words, the benefits of this cargo throughput are not felt within the port community in the same manner that cargo bound for the port region represents. Thus, some ports reach a point where the incremental benefits of port expansion begin to decrease.

The question remains, what is the necessity and public desirability to compete for cargo not destined for the port's region? The role of a public port should not be to make money. It is to function as a self sustaining economic entity much the same way that public utilities are run. It is this clash between economics and public welfare that guides the recommendations for managing a growing overcapacity in the nation's container ports.

The situation in San Pedro Bay illustrates this conflict. The recently completed 2020 plan for the Ports of Long Beach and Los Angeles in response to the projected increase in Pacific Rim trade represents an attempt to manage inadvertent overcapacity and inefficient use of coastal ocean space with respect to port growth. The plan also attempts to alleviate the stress placed upon transportation infrastructure as a result of new development. But this plan incurs specific costs that the public will bear. The estimated construction and implementation costs are estimated to exceed 5 billion dollars.[17] In addition, these ports are by no means assured access to the projected increase in trade, and this construction may, despite planning, result in overcapacity and underutilized infrastructure. From a regional perspective, other ports may be in a better position to handle the projected Pacific Rim trade and may service this trade more efficiently at a reduced cost.

While it is encouraging that these ports are at least planning on a small scale regional basis, the projected increase in trade is likely to effect the entire west coast port range. Management of container terminal capacity at this level would most assuredly result in better efficiency in coastal ocean space utilization and improved economic efficiency in existing ports throughout the region.

In order to improve the public accountability of public port actions, and improve the management of excess overcapacity, there are many actions which could be taken at the federal, regional and state levels. The rest of this paper examines the present roles of these governmental levels with respect to the management of overcapacity and assesses what roles they could play in the future.

FEDERAL PORT POLICY AND OVERCAPACITY OF CONTAINER FACILITIES

Federal policies pertaining to port development have historically been institutionally fragmented and short on focus. Federal port policy has been limited by Article 1, Section 9 of the Constitution which states that:

> No preference shall be given by any regulation of commerce on revenue to the ports of one State over those of another: nor shall vessels bound to, or from, one State, be obliged to enter, clear, or pay duties in another.

This limits federal and state regulatory powers and prevents them from imposing either a discriminatory or competitive bias. Other factors have prevented the assertion of any strong federal port policy. The structural fragmentation and jurisdictional conflicts in the congressional committee structure lend themselves to constraining any assertion of unified policies pertaining to port development.

Most federal port policy takes place at the regulatory level. These federal agencies effect port development in three ways: (1) through the allocation of federal funds for port related projects; (2) through the implementation of regulations pertaining to the siting and operation of terminal facilities; and (3) through the formulation of policy that directly and indirectly affects ports. Much of the federal regulation and policy deals with the environmental effects. The environmental regulatory responsibilities imposed on ports are fragmented and split among different agencies of the federal government such as the Army Corps of Engineers (COE), the Coastal Zone Management Program, and the Environmental Protection Agency (EPA). This fragmentation serves as a barrier to unified policies pertaining to the national port industry.[18] The federal deregulation of transportation industries and the change in the nature of the traditional "partnership" pattern of port development have also prevented any strong assertion of federal port policy.[19]

Yet, at the conceptual level there is the strong need for a federal port policy. As the ever-present effects of an intermodal transportation system take hold, and the competitive pressures of containerization are felt by the nation's ports, there is a strong desire to prevent an excess capacity of container terminal facilities at both the regional and national levels. This federal interest is felt in the desire as a nation to operate in as economically efficient a manner as possible and to provide the best possible service at the lowest possible cost in order to take advantage of the opportunities presented through economies of scale. There is also a federal interest to operate in a socially efficient manner and to minimize the detrimental environmental effects of unnecessary expansion. Environmental degradation is a social cost felt by the nation as a whole and there is a strong federal interest in the preservation and protection of the marine coastal environment. As such, there has been significant federal participation in land use planning and decision making in the coastal zone.[20]

The federal government also has a monetary interest in preventing the development of excess overcapacity. Federal money is often spent directly or indirectly on projects affecting port development, including highway construction and channel and harbor maintenance. While federal policy has shifted towards increased cost sharing between the state and federal government, the efficient expense of federal money is desirable. This is especially true in the present era of budgetary shortfalls and the advent of the "new federalism." Thus, federal expense and environmental regulation should stem overcapacity in port facilities.

The Federal Role in Port Development

This raises the question of the federal role in port development with respect to excess overcapacity in container facilities. As mentioned previously, there is a desire at the federal level to maintain a significant level of overcapacity. At the same time there is an interest in the orderly development of an economically efficient transportation network of ports, railroads, and highways which does not impose significant social costs on the nation with respect to environmental degradation and inefficient use of public lands.

The federal government can play a stronger role in the supervision of port development without impinging on the competitive nature of the industry. In some respects, the formulation of a national port policy would be useful to guide national port development as it expands to meet the growing demands of intermodalism and world trade. While there are many difficulties involved in the formulation of federal port policy, the integration of existing federal port policies is an excellent place to start.

A coordinated approach within the environmental permitting and regulatory process would be beneficial to quell the growing overcapacities at regional and state levels. For example, environmental impact statements prepared under the National Environmental Policy Act could be required to recognize regional forecasts of overcapacity with respect to the requirements for construction. The Coastal Zone Management Act could be used to facilitate port planning with respect to overcapacity at the state level. The EPA and Army Corps of Engineers should, within their permit reviews, coordinate efforts with other agencies in order to ascertain required dredge and fill operations with respect to desired levels of overcapacity.

The federal government has a stronger role to play at the regional level with respect to annual or semi-annual reviews of container capacity. It is suggested that this review process and the supervisory role could be handled by the Maritime Administration (MARAD). MARAD could serve to coordinate environmental regulation of various federal and state regulatory agencies to minimize detrimental effects of overcapacity at the regional level. It could also serve as the technical consultant and conduct the capacity review. It could sponsor annual or semi-annual meetings for port managers, state officials, and the public in an attempt to manage container overcapacity in a more efficient manner.

What is not suggested is direct federal involvement in the determination of overcapacity. This determination is best left to political and economic processes at the state and regional levels. An indirect assertion of federal policy can help to stymie unnecessary port development while preserving the present competitive nature of the industry. In this way, the system is more likely to err on the side of excess overcapacity. In the case of the port industry, it is better to err on this side than to incur regulatory burdens which prevent the capacity needed to service increases in trade.

STATE/REGIONAL POLICIES AND THE MANAGEMENT OF OVERCAPACITY

State port policy in the U.S. is administered by individual state port authorities. The policy directives outlined in most port charters focus upon increasing cargo throughput and improving local economies. Any policy relating to land conservation may exist in a port charter or as an inherent factor of public accountability. The assurances of any such policy can not be guaranteed due to the lack of a reliable political mechanism. Generally, port development goes unchallenged by the public due to assumptions that all port development is required to remain competitive.

Regionally, states are not required by federal law to cooperate or engage in joint management. Under a competitive system, it is unclear whether regional management involving more than one state is mutually beneficial. Each state gains economic benefits from trade revenue. In theory, inter-state competition distributes this wealth efficiently. Consequently, port competition presents barriers to a cooperative management structure. Efficient inter-state port management implies cargo allocations. In the case of containerized cargo, regional management also requires that all ports agree on cargo allocation decisions. The problem with this proposition is that each state port has different goals, mainly involving gain at the expense of others. Potentially, a port can attract all of the cargo in a region if it is big enough. The main question here is, why sacrifice any cargo, if you could have it all? Although the existing competitive system may provide economic justification for state rather than regional or federal port management based on market theory, it does not provide for the efficient allocation of coastal land. For this reason, capacity review on a state and regional level may be necessary.

But there are barriers to successful state and regional management structures. Regional management can not occur effectively unless ports have the same goals. Until they can be convinced that regional management will result in benefits to all involved, cooperative management will not occur on a voluntary basis. There have been examples of this cooperation, but they have fallen short of achieving better land-use efficiencies from a public perspective.

In response to the charges of overcapacity in the 1970', and due to the increasing difficulty in financing container facility development, cooperative management was voluntarily formed in Washington.[21] Subsequently, the Cooperative Development Committee (CDC) of the Washington Public Ports Association (WPPA) was formed to review port projects. Though functioning particularly well in sharing capacity information among ports, there were free-riders and no sanctions for noncompliance.[22] CDC in Washington was an attempt at preventing redundant facilities and improving efficiently; however, according to Levie, the Association did not coordinate planning efforts with other public officials and thus precluded any effective regional management.[23] Regional or coordinated state management must consider port needs in conjunction with other social welfare functions such as public land-use opportunities. In other words, a multiple use planning effort in state government involving port managers, regulatory officials, and the public is required. Whether or not such management should be mandated is beyond the scope of this paper. The competitive port system in the U.S. is the best system available and should remain intact, however, to prevent wasteful use of public coastal space, policy must be reevaluated and designed to meet these conservation goals.

Understandably, ports are not primarily concerned with land conservation. As a public agency competing for international trade, the port is ultimately concerned with sustaining its viability and success. Permit review is left to other state agencies. However, these agencies do not base their decisions upon productivity and capacity information. While assuming that the ports require expansion, factors such as land conservation and environmental concerns form the basis of local governmental decision-making. Perhaps this check is sufficient. But if local government and other state agencies involved in land-use development were provided with capacity information, a more facilitated decision-making process involving cooperation between port management and other public officials could occur. Port activity and coastal land-use go hand in hand. Port and coastal space management should therefore be coordinated. Intrastate cooperation in this context, implies improved efficiency in government. Not only will the port benefit from accurate productivity and capacity assessment, but inter-agency review of this information can facilitate decisions concerning coastal space utilization.

An important point to be made is that regardless of accurate productivity and capacity monitoring, overcapacity may still occur. Port expansion and improvement requires many years of planning and development. Ports are forced to develop according to anticipated cargo rather than proven growth. Thus, there is bound to be a certain amount of excess capacity. The goal of public policy should be to decide how much of this excess should be allowed. This determination can only occur with port cooperation and the availability of all relevant port information. The utilization of a capacity review and intra-agency cooperation will lend itself to maximum attainable efficiency in planning within the competitive framework. Thus, it provides a mechanism for limiting overcapacity on a local and regional level.

CONCLUSION

Inter-port competition in the U.S. has resulted in an expansive port system and the development of large container facilities. Within a region, duplicate facilities suggest overcapacity. This overcapacity represents social inefficiencies in coastal land utilization, public expenditures, and environmental degradation. As container development continues, unbridled expansion by politically autonomous public ports threatens to increase these inefficiencies. A certain level of autonomy must be preserved for ports so that they can operate effectively in a competitive world economy. As public entities, ports are accountable to the public for their actions. In order to prevent the social inefficiency represented by excess capacity, a policy designed to coordinate port management, and the regulatory system is needed.

This paper has suggested that capacity review be involved in a coordinated state or regional planning effort as a means to allow for more efficient coastal space utilization. It has also suggested that such a review is good public policy. Perhaps it is time to draw the line with respect to total port autonomy. The realization that port activities can concurrently increase economic benefits to a region and incur social costs demands attention. Hopefully, the future will bring more efficient use of the nation's dwindling coastal ocean space and maximize the benefits of its use to society as a whole.

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The Taiwan Area Deep Water Port Preliminary Planning Study

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ABSTRACT

The Deepwater Port Development (DWPD) Projects Study, which began in February, 1989, was completed in June 1990. This study examined the feasibility of building a deep water port on the northern and western coasts of Taiwan, in one or more of the five preselected sites: Keelung, Tamsui, Taichung, Waisanding and Kaohsiung.

The purpose of the first phase of the study is:

— to identify the needs for a deep water port in the Taiwan area and the possible development alternatives to meet them;
— to check the economic, technical and financial feasibility of these alternatives;
— to compare them and recommend the most satisfactory.

At the end of the first phase, the project of an industrial port, designed to accommodate a power plant, a steelworks and a refinery at Kaohsiung, was recommended.

The second phase of the study analyzed implementation of the selected project in greater detail: the master plan, economic performance, and financial organization.

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INTRODUCTION

The Republic of China's (ROC) economic history shows the importance of foreign trade in the general economic development of the island of Taiwan, mainly based on export and industrial activities. In this context, Taiwan has been favored for its geographical location in the Asia-Pacific region, and a strong maritime orientation.

Out of a total of 101 million tons (mt) of seaborne exports and imports in 1987, two main categories involving different shipping patterns and port facilities are to be considered:

— Marine imports in bulk for the energy sector (coal and crude oil) as well as ores and raw materials for basic heavy industries (steel and chemicals) represented more than 65% of the 83 mt of imports in 1987.

— General and containerized traffic reflect the imports of intermediary and capital goods in the manufacturing sector (19.3 mt) as well as exports of final products (12.4 mt.)

In 1988, foreign trade through the ports soared, with a 14.2% increase resulting in a 115.5 million tons total. This increase is related only to massive energy and basic industrial bulk, containerized traffic remaining stable at around 21 million tons. On the other hand, crude oil, coal and mineral ores significantly increased by a total of 11.3 million tons.

Each harbor experienced this increase:

— for Kaohsiung harbor, an increase of 15.4% in 1988, mainly due to soaring of bulk and non containerized traffic,

— for Keelung harbor, a slight increase of container traffic imports, but significant decrease as far as export tonnages are concerned.

— for Taichung harbour, an increase of container traffic which nevertheless remains below its regional potential.

Recent container traffic is marked by a decrease in export tonnage, and an increase in import container tonnage. Another major change observed is the significant decrease of empty boxes (imports), an evolution related to the relative stagnation of exports and simultaneous decrease in average tonnage/ TEU resulting in a better balance of box movements.

Future shipping patterns can be based on probable source diversification with a notable increased share of Southeast Asian supplies. Due to the importance of tonnage to be imported from this region, the share of large vessels is expected to be significant at the 2000 horizon, and increasing in the very long term (60% in 2011). On the traditional tanker routes from the Arab Persian Gulf to Taiwan, the remaining tonnages can reasonably be transported on large tankers (200,000 to 250,000 dwt).

As the major part of coal and ore imports will remain on long-run routes and because of the huge amount of cargo to be transported, future use of large bulk carriers could be considered as an opportunity, as for tankers, for freight fixtures attractivity. Typical ships to be considered are 150 to 200,000 dwt bulk carriers, and 250,000 dwt class ships in the long-run provided that this alternative is proven economically attractive.

Forecasts confirm the expected increase in ports traffic for Taiwan. This increase will be particularly important with regard to the goods in containers which are likely to play a key role in economic development, particularly in the exports. Although the forecasts represented in this respect are far below the figures usually quoted in Taiwan, they clearly show the need for urgent development in the capacity of Keelung port and for the continuation of the development of Kaohsiung port. Although the facilities required are not deep water facilities (in the sense of depths alongside the quays larger than those available now), possible layouts at Keelung will be designed as a response to this need.

In Kaohsiung existing projects at terminal 5, and if needed terminal 6, will meet the traffic requirements for the years after 2000. Taichung is not likely to experience an immediate growth in container traffic; and the existing facilities will be adequate for forseeable future.

The traffic of goods in bulk will also experience a significant increase, particularly as far as imports are concerned. This is related to the scarcity of raw materials in Taiwan. Among these goods, only the following could benefit from transportation by large vessels (more than 125,000 dwt carriers requiring depths larger than 16.5 m):

- crude oil;
- coal for power generation; and
- coal and iron ore for steelmaking.

The need for the Taiwan economy to increase the imports of these goods is obvious. Although it is always possible to import refined and steel products, crude oil refining and steelmaking are strategic activities in a modern economy and are in the interest of CPC and CSC for future development in their respective sectors.

With regard to power generation, Taiwan Power Corporation (TPC) is looking for the diversification of energy sources and to keeping the cost of electrical power as low as possible. Coal should continue playing a significant role in the development of the production and TPC has confirmed its interest in increased coal unloading facilities.

Deep Water Port planning should then consider, at the same time, the port facilities and the industrial land available for development.

COMPARISON OF ALTERNATIVES

Possible alternative schemes were compared for deep water ports able to receive the forecast future traffic which will likely rise for large vessels: crude oil, coal for power generation, iron ore and coal for steelmaking.

To accommodate this traffic, five ports or sites were considered: Keelung, Tamsui, Taichung, Waisanding and Kaohsiung. The design of the identified alternatives was based on the analysis of physical conditions at the five sites.

The alternative developments studies were then compared from several points of view, including financial and economic aspects. A multicriterion analysis was developed. Obviously, this multicriterion analysis would only show which was the best among these possible projects but would be unable to show that it is better than a project without deep water facilities. So for the purpose of comparison, a "reference case" was also developed without deep water facilities but which can receive the maximum size of vessel which can presently be accommodated in Taiwan ports.

RECOMMENDED DEEP WATER PORT DEVELOPMENT (DWPD) PROJECT

The recommended DWPD project is divided into two phases:

- First phase:

— Land for Kaohsiung City Government (KCG)
— Steelworks (CSC)
— Tank farm (CPC)

- Second phase:

— Land for the development of Kaohsiung Metropolitan Area (KMA).
— Airport

The land area required to complete the first phase is 3,357 ha; for the second phase, 2,820 ha. Therefore, total area to be reclaimed is 6,177 ha.

Considering the land area required for industrial and urban development (6,177 ha), and the natural limits of the project toward the north (second entrance of Kaohsiung harbor) and the south (mouth of the Kaoping river), the only way to meet the requirements is to extend the port off shore to water depths of 30 meters.

PREPARATION PHASE FOR FURTHER STUDY

This extremely large project, and its associated high cost, calls for extraordinary care in preparation of the detailed design, specifications, and tender documents as well as for prequalification of contractors, evaluation of tenders, preparation of contract documents, and the supervision of construction.

Before — or at the same time as — the detailed design of the project is drawn up, various studies have to be carried out, including additional field investigations, Environmental Impact Assessment, and mathematical and physical models. To prepare the above mentioned investigations, and also to update the basic design of The DWPD project, a planning and basic design study is suggested.

1. Additional site investigations have to be carried out:

— topographic and hydrographic survey,

— oceanographic surveys including sea level observation, wave data, currents in dry and wet seasons with current meters, sediment samples of sea bottom, and seawater samples,

— meteorological data (wind speed and direction together with air temperature and humidity),

— geotechnical investigations for reclamation and port structure areas, as well as for marine borrow areas, including magnetic and side scan sonar survey, seismic reflection survey, borehole survey, and laboratory tests, and for rock quarry sites (seismic refraction, field tests by drilling and laboratory tests).

The cost estimate of site investigations amounts to NT$167.5 million.

2. Environmental Impact Assessment (EIA)
— physical environment
— ecological environment
— human environment

3. Mathematical and physical models

— Numerical models in order to study wave disturbance, surge, typhoon, harbor resonance, coast evolution, hydrodynamic current patterns, suspended sediment dispersion in the far field area, the risk of industrial and organic pollution, and the risk of recirculation of the discharged heated water by outfall structures, improvement, if necessary, of the water renewal rate in the coastline channel.

— Physical models required for wave disturbance, ship motion, completing the results of the coast evolution numerical model, stability test (2D and 3D) in order to optimize the cross sections of hydraulic structures (breakwater, seawalls, etc.

4. Planning and basic design

Before starting the detailed design, the following is in order:
— update the layout recommended in the current study,
— prepare and monitor the site investigations,
— prepare the preliminary design of the structures.

5. Detailed design

The detailed design should conform to the highest standards and should be based on clearly sufficient information with regard to physical conditions at the site and availability of construction materials.

CONCLUSIONS AND RECOMMENDATIONS

At the end of the study, it can be concluded that:

The traffic forecasts up to the year 2021 have demonstrated that there will be a definite increase in crude oil, coal and iron ore traffic which can be imported through deep water port facilities.

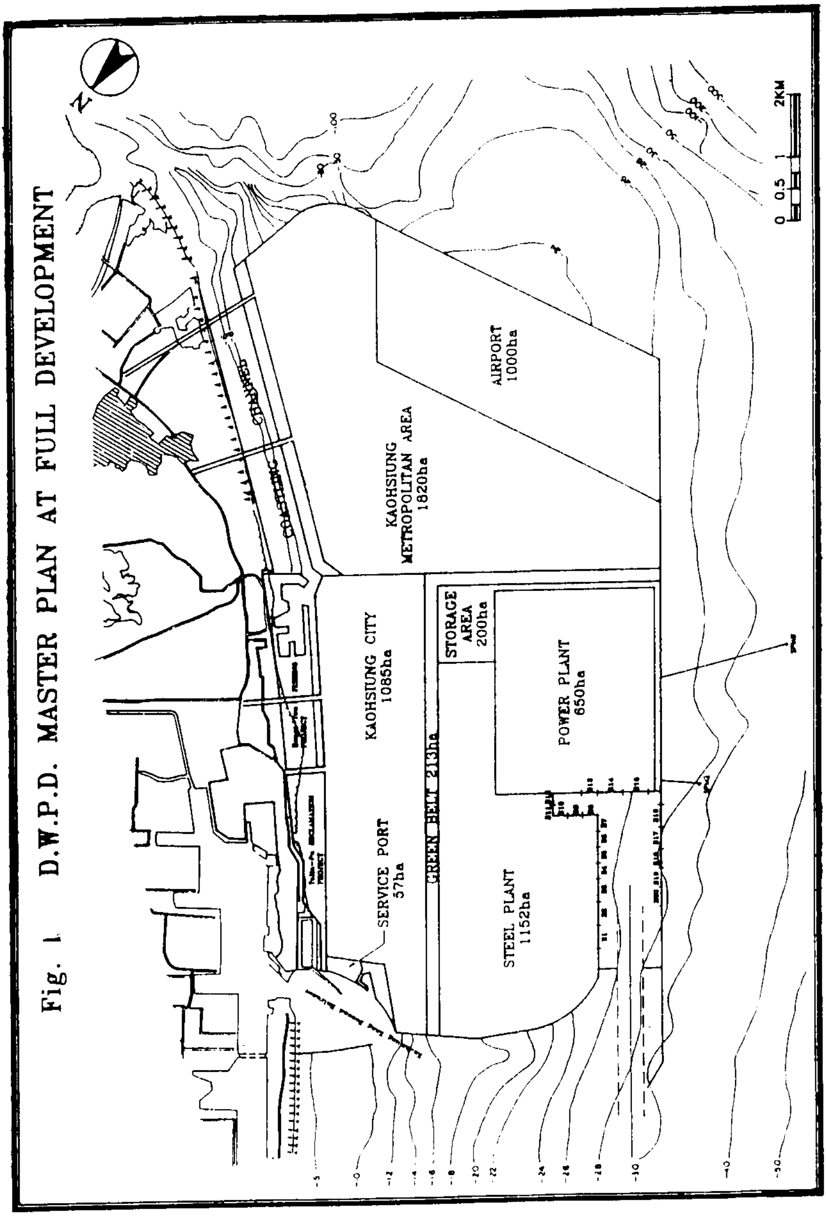

Figure 1. D.W.P.D. Master Plan at Full Development

• Industrial user requirements are prone to evolve in the future; and other users are also lacking land in Taiwan.

• With the help of a multicriterion analysis, Kaohsiung was selected as the most suitable site to set up a deep water port with the related industries. Being that Keelung is not suitable for a deep water port, Taichung is ranked second, Waisanding third, and Tamsui fourth.

The recommended project at Kaohsiung amounts to NT$315 billion (construction cost) to be shared over 19 years. It will provide a large land area (6,177 ha) for industrial purpose, but without raising problems of land acquisition, or manpower.

• The DWPD project is technically feasible, but some construction methods — dredging works in particular — have to be suited to the magnitude of the project.

• The environmental impact of the DWPD is acceptable on the condition of implementing some mitigative measures.

• The DWPD project is economically and financially feasible. The economic indexes are:

	IRR%	B/C ratio
Port	13.8	1.387
Industrial land	12.0	1.154
Total	12.5	1.170

Furthermore, the selling prices for the users are reasonable: approximately NT$6,000 per in current prices.

For the implementation of the DWPD project, we recommend:

• Create an authority to coordinate, manage and supervise the project during the construction works phase and its preparation.

• Set up the project financial plan which allows the flexibility of port activity and development in the future, and ensures a satisfactory income to The Harbor Bureau without any changes to the tariff system.

• Immediately implement several tasks before the beginning of construction: field investigations hydraulic studies, planning, basic and detailed designs.

• The Kaohsiung City Government and the Kaohsiung Metropolitan Area must set up a Land Use Plan in accordance with the industrial port development.

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Redevelopment of Ports and Harbors in Hokkaido

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ABSTRACT

The plans for redevelopment of ports for the future must take a new approach, setting as the goal a "comprehensive port space" made up of a harmonious blend of freight handling facilities, processing facilities and public spaces. This concept has been incorporated in the ongoing projects for redevelopment of the harbors in Otaru, Kushiro and Hakodate. The results of these efforts have led to the following conclusions:

1. It is essential to plan for more public spaces in ports, in balance with the other functions, freight handling and industry.
2. Designers must also give full consideration to the character of the city behind the harbor when planning recreation facilities.
3. The routing of traffic flows among the freight handling areas, industrial areas and public areas must assure safety and convenience for all concerned.
4. The facilities in a port space should be attractive and fit with the scenic beauty of the harbor.

INTRODUCTION

Profile of Hokkaido

Hokkaido is an island in the northern part of Japan. Its area is 83,409 square kilometers (33,219 square miles) and it boasts 4,298 kilometers (2,671 miles) of

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coastline, 22.1% of the total land area and 12.5% of the total coastline of the country.

Its population in 1988 was 5,670,000 with earnings of ¥11 trillion ($85 billion at ¥130 = $1), 4.6% and 4.2% of the national totals respectively. As Figure 1 shows, Hokkaido has 37 operating ports and harbors, of which 2 are specially designated major ports, 11 are major ports and the remaining 24 are local ports. The freight handled at these ports amounted to 156 million tons in 1988, 5.2% of the national total. Thirty-three million tons (21.1%) of this was foreign trade, while the balance was domestic.

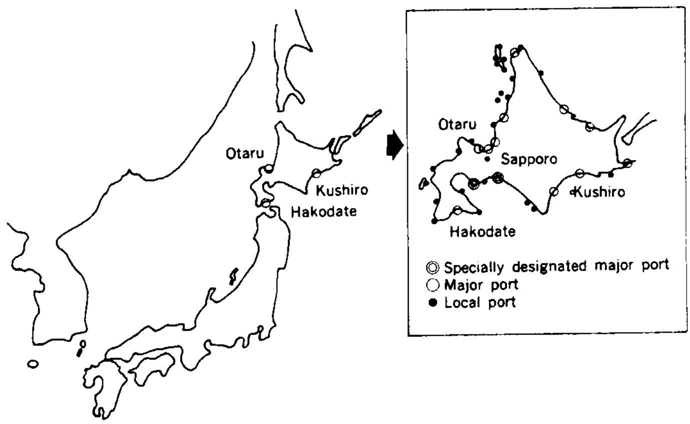

Figure 1. Location of ports and harbors in Hokkaido

Redevelopment of Ports in Hokkaido

The exploitation of resources from the bounteous seas surrounding Hokkaido has a long and successful history. Development of areas close to the shore and trade between the natives of Hokkaido and other regions of Japan began long ago. One of the goals of the Meiji administration (Meiji Period: 1868-1912) was the settlement of this island; they perceived the necessity for port facilities for the admittance of settlers and goods and the outlet of local products. During the decade between 1910 and 1920, facilities were constructed at Hakodate, Otaru, Kushiro and Rumoi; the next decade saw an acceleration with the development of Muroran, Wakkanai and others. These relatively old ports of Hokkaido still have breakwaters and wharves which date from before the Second World War. Thus, there remain many aging and deteriorating facilities, and their replacement has become an increasingly urgent issue. The Ports and Harbors Bureau of the Japanese Ministry of Transport has released a paper titled "Ports and Harbors Toward the 21st Century,"[1] which outlines a policy of the comprehensive design of "port spaces:" A harmonious blend of freight handling facilities, processing facilities and public spaces. A master plan for Otaru Harbor, Kushiro Harbor, Hakodate Harbor, Muroran Harbor and others is now under discussion. The intent of this paper is to introduce some of the present and future projects and explain the plan for comprehensive redevelopment of Otaru Harbor, Kushiro Harbor and Hakodate Harbor into living and working spaces for people of the twenty-first century.

Comprehensive Port Spaces

"Ports and Harbors Toward the 21st Century," released in April, 1985, detailed the long-range policy of the Ports and Harbors Bureau of the Ministry of Transport for refurbishing this country's harbors in preparation for the next century. That report explained a change in the administrative philosophy, from an emphasis on design for the ability to handle ever-increasing amounts of freight and exploitation of an expanding amount of land for industrial purposes, to an emphasis on design of spaces accommodating both people and things for a variety of purposes — play as well as work. The new policy envisages a comprehensive "port space" which combines freight handling, industrial uses and public/recreational facilities into a comfortable, efficient and harmonious environment. The report explained some of the specific goals serving these three functions as follows:

1. The goals of a modern cargo handling system are low cost, speed and adaptability. These will be served by a comprehensive freight terminal combining modern information systems and storage facilities and a modern road system serving the harbor and its environs. Procedures for incoming and outgoing shipments must be simplified and automated. Safer and more capacious shipping lanes and wharves are also needed.

2. A modern industrial facility is more than just a factory. It must be flexible enough to adapt to the constant developments in industry, which are not only technological but are also responses to the demands of the increasingly international market as the demands are relayed by the increasingly effective information network. At the same time, it should offer sophisticated cargo handling facilities, space for international exhibitions and conferences, and research and communications facilities, all in an environment softened and humanized by green space. Finally, each port should provide opportunities for expanding local industries and services.

3. Lively public areas offering a variety of opportunities for recreation must also be a part of the modern "port space." These will offer citizens precious opportunities to refresh their appreciation for the ocean and its many gifts to mankind. Besides the construction of marinas and beaches for swimming and sunbathing, ships and sea can be combined in facilities for community events and activities while historic harbor institutions and the scenic beauty of the ports are preserved. Finally, it is essential that all facilities must be sturdy against earthquakes and tidal waves and protect the cleanliness of the environment.

REDEVELOPMENT OF OTARU HARBOR

Profile of Otaru Harbor

As shown in Figure 1, Otaru is on the Japan Sea coast, about 30 kilometers (20 miles) northwest of the capital city of Sapporo. It is an important port in the central Hokkaido area, handling 11.7 million tons of cargo in 1988. There are seven piers in Otaru Harbor (Pier 1, Pier 2, Pier 3, Chuo Pier, Katsunai Wharf, Ironai Pier and Umayamachi Wharf), the deepest anchorage of which is in 12 meters (39 feet) of water.

Otaru is favored with a natural harbor; it has been used as a fishing base for many years. The first stone wharf there was laid in 1872, and the harbor was connected with Hokkaido's first railroad line in 1880. Otaru was soon busy with outgoing coal shipments. A major expansion of the port facilities was begun in 1897, resulting in the following important milestones: A north-south 4-kilometer (13,120 foot) long breakwater (completed 1921), Umayamachi Wharf (completed 1934), Pier 1 (completed 1937), Pier 2 (completed 1941), Pier 3 (completed 1954), Chuo Pier (completed 1972), and Katsunai Wharf and Ironai Pier (completed 1982).

Figure 2 shows the districts making up Otaru Harbor. Each has the following facilities:

1. Takashima District: An area for handling fish
2. Temiya District: A cargo handling area, headquartered on Umayamachi Wharf and including Ironai Pier. It is equipped with tanks for petroleum products, cement silos and the like.
3. Chuo District: A miscellaneous freight handling area, equipped with a complex of warehouses behind Piers 1-3. Behind this lies Otaru Canal, part of which is used for anchoring small craft.
4. Katsunai District: A wharf in 12 meters (39 feet) of water, handling mainstay products such as cereal grains and minerals. This is also a base for ferries and container vessels operating on the Japan Sea.
5. Wakatake District: A pier for raw lumber, incorporating a timber pond.

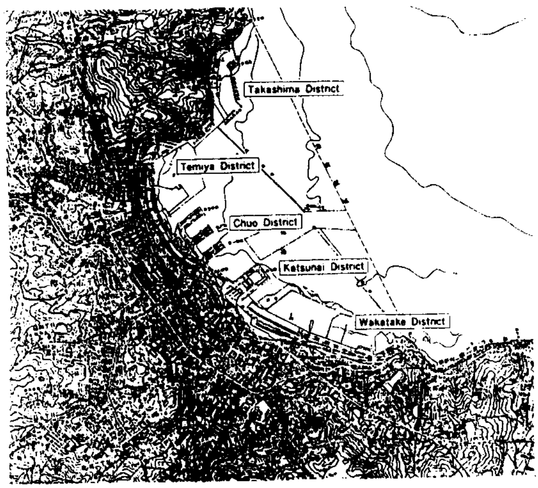

Figure 2. An overview of Otaru Harbor

Problems Facing Otaru Harbor and the City of Otaru

Otaru has many buildings and places of historic value, and these should be used to full advantage to create a city of lasting beauty and interest to tourists. The population has been dropping since 1960. Otaru is a popular tourist destination, but 90% of the tourists come only on day trips, and there are insufficient parks or other recreational areas along the waterfront. With its mountains close to the shoreline, Otaru's geography precludes much industrial expansion. At the same time, the obsolescence and deterioration of the existing port facilities are preventing full utilization of the port and its natural cargo capacity. There is a pressing need to modernize and expand the port facilities as the demand for cargo handling is rising and the character of cargoes has changed in recent years.

Fundamentals of a Program for the Redevelopment of Otaru Harbor

The redevelopment of Otaru Harbor must be more than just an answer to the problems of the harbor and its facilities. As the harbor is directly contiguous to downtown Otaru, the redevelopment will be planned with due consideration for the needs and handicaps of the downtown environment, especially the limitations on expansion and land use imposed by the mountains in the west of the city.

1. Renovation and expansion of cargo handling facilities: An essential part of the renovation is the outfitting of the port with equipment for essential new functions as well as replacement of aging and deteriorating port facilities. The position of Otaru Harbor as a freight base must be ensured by the modernization of

the cargo handling systems and other services. Also, passenger facilities must be improved for the ilse of international tour vessels.

2. Rebuilding a unique and beautiful Otaru: The unique points of this city must be brought out and enhanced in order to attract tourists, who play a vital role in the economy of Otaru. Part of the existing downtown area will be redeveloped in tandem with the harbor district to create the beginning of a new Otaru.

3. Evolution of a waterfront acceptable to the citizens of Otaru: Barks and other recreational areas and facilities are being planned to encourage citizens and visitors to enjoy the waterfront.

4. A zone for industry: Industries, both previously existing and new, will be encouraged to develop and expand. Space will be set aside for new industries, for example, those connected with marine sports, to come and establish themselves.

5. Construction of ocean recreation facilities: The marina will be the centerpiece of a new marine sports park where citizens of nearby cities as well as of Otaru can come to enjoy themselves.

6. Redesign of streets and access roads: Streets and traffic facilities will need to be improved so that citizens can take advantage of the new waterfront.

Zoning for the Redevelopment of Otaru

The functions of each zone in Otaru Harbor have been reconsidered in terms of how they should conform to the aims of the redevelopment. The zones are shown in Figure 3.

1. Takashima District: This contains the fisheries zone, where a cooperative effort in the expansion of fish farming is planned in the future. This district faces the open sea, and its functions as a general fisheries zone will be expanded. Fisheries research facilities are planned here in the future.

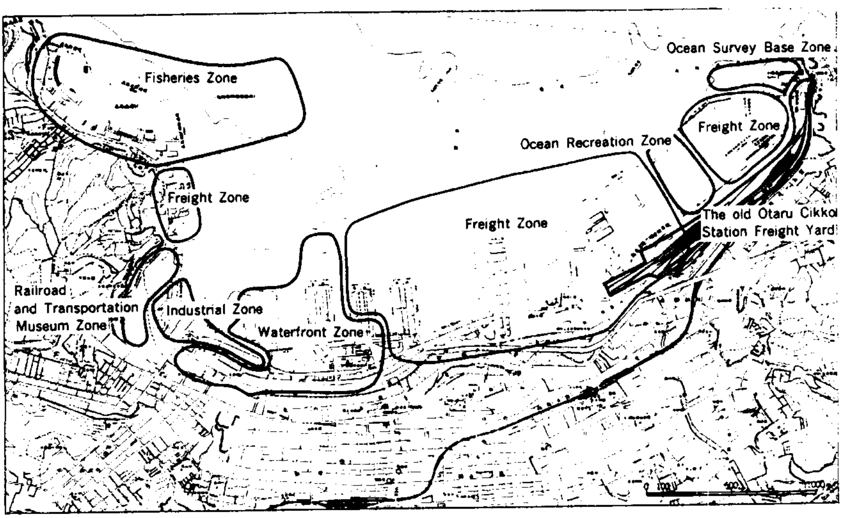

Figure 3. Zoning for redevelopment of Otaru Harbor

2. Temiya District: This contains Umayamachi Wharf, which handles dangerous cargoes and others, and its functions will be expanded. On Kitahama Wharf mills and other industries already stand, and these will form the base for additional industrial operations. Also, this is the original location of Otaru Harbor, so with its previously existing tourist attractions such as Temiya Cave and the Railroad Museum, it is certain to remain a recreational choice, as echoed in its name "Transportation Museum Zone."

3. Chuo District — Pier 3 and Environs: Pier 3, Otaru Canal and Ironai Pier are all adjacent to downtown Otaru. Besides the canal, this area boasts a number of tourist attractions in its historic buildings and its long shoreline. This will be the "Waterfront Zone" for the recreation of Otaru citizens and visitors.

Pier 1 and 2 are freight-handling areas; thus, there must be a "buffer space" between these and the city and recreation areas. The demand for space near the downtown area is also very high, so the "buffer space" will be zoned for office buildings and parking areas.

4. Chuo District — Pier 2 to Katsunai Wharf: These are the main freight-handling areas of Otaru Harbor. They will need to be renovated for several functions, including passenger-carrying ferries.

5. Wakatake District: Some of the space in the north section of the timber pond has become redundant, as less timber from Southeast Asia is coming through the port now. There are increasing public requests for marina space in this area, which will be taken into consideration during plans for the Ocean Recreation Zone to be built here.

The south section of the timber pond will continue to be used for that purpose, but with an eye to changes in the demand for lumber in Hokkaido. This area will be allotted for public space in the future.

The tip of the south section faces the open sea. This area is at a distance from the present routes into and out of the harbor and has been designated an "Ocean Survey Base Zone."

The old Otaru Chikko Station Freight Yard is located behind what will be the Ocean Recreation Zone. This presently unused area is close to the entrance and exit to the tollway, and will be zoned for multiple uses.

Some Projects in the Redevelopment of Otaru

Next, some ongoing and some completed projects in the above described plan will be introduced.

1. Otaru Canal: The Otaru Canal was completed in 1923. Its length was 1324 meters (4343 feet), its width was 40 meters (131 feet) and its depth was 2.4 meters (8 feet). The cargo handling capacity of the harbor was increased by this work, vastly reduced. However, after that, as ships began to dock at deep-water piers and the process of loading and unloading no longer required shallow draft barges, the canal itself was rendered obsolete. By 1960, it had become full of sludge and a source of offensive odors. A plan to fill in the canal and use the land space created

as a new city arterial was proposed in the late 1960s. This was met by bitter opposition by a group of citizens who wanted to preserve the old stone warehouses in the vicinity of the canal as well as the scenic beauty of the canal itself. Ultimately, part of the canal was filled in for the arterial, and the remainder was preserved as a scenic space for the enjoyment of the citizens. Presently, over one million visitors come to the old Otaru Canal area each year. More than a recreational area for citizens, it has become a center for the revitalization of the Otaru legion.

2. Otaru Marina: The north part of the timber pond in Wakatake District has been designated as a Ocean Recreation Zone. Operations to construct a marina in part of the timber pond began in 1988, and the partially completed marina opened for business in April, 1990. The capacity of the marina is 200 floating berths, 100 dry berths and 50 visitors' berths. Because of Hokkaido's winter conditions of heavy snow and a long cold season, there were fears that few sailboat and motorboat owners would appear to request berths, but perhaps because of the proximity of Sapporo with its 1,700,000 population, requests flooded in, filling the marina nearly as soon as it had opened, to the delight of the owners.

3. Initiative for Redevelopment of Chuo District: All three roles of Otaru must be kept in mind during the redevelopment of Chuo District. It must be not only a cargo-handling harbor, but also a recreational area and a comfortable living environment. These functions are visualized as follows:

New Harbor freight-handling facilities will be built, incorporating modern concepts in shed and warehouse complexess management and services. Designs will allow flexibility for the increasing size of ships and changing configurations of cargoes.

Recreational facilities will be established for the enjoyment of the citizens and as a symbol of Otaru; accommodations and international convention facilities will be constructed to increase the volume of visitors for sightseeing and overnight stays.

As the harbor is directly adjacent to the downtown area, a "buffer space" consisting of harbor management and administrative offices and other functions will be created between the two areas, with due considerations to preserving Otaru's scenic beauty.

A schematic view of our proposal is shown in Figure 4.

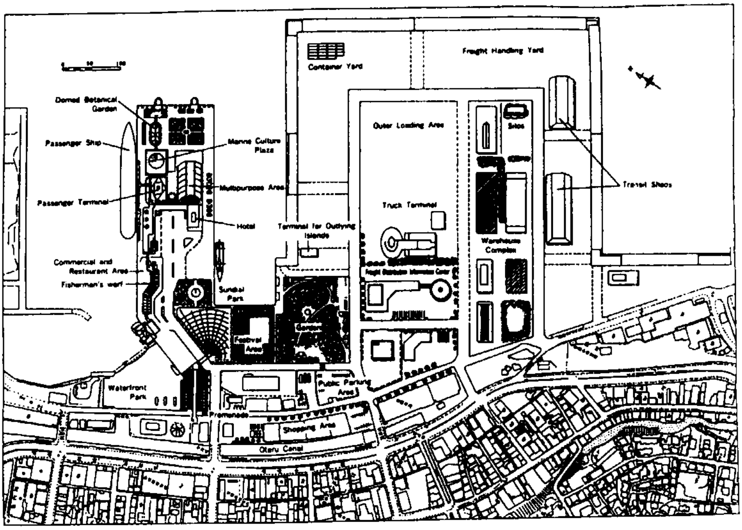

Figure 4. Proposed layout of facilities for redevelopment of Chuo District

REDEVELOPMENT OF KUSHIRO HARBOR

Profile of Kushiro Harbor

As shown in Figure 1, the old port and industrial center of Kushiro is located in the east of Hokkaido. It is a major port, handling 19.71 million tons of cargo in 1988, and the natural center of activity for the entirety of East Hokkaido. It has a long history as a port; construction of the breakwater began in 1910, and the 1409-meter long (4622-foot) south breakwater was completed in 1932. Construction and improvements have never stopped; in 1969, in anticipation of increased activity with the establishment of container shipping and ferry lanes, port authorities ordered construction of West Kushiro Harbor. In contrast, East Kushiro Harbor still has much equipment which dates back to the 1930s, a lot of which is old and in bad repair. This section will detail the ongoing redevelopment of East Harbor.

The Division of Functions between West and East Harbors

Kushiro Harbor is divided in terms of location and history of development into an east harbor and a west harbor. The functions of the two are also divided as described below.

1. West Harbor, constructed during a relatively recent period, is now used for bulk cargoes (petroleum, chips, grains and others), ferry traffic and container ships. Coordination with fishermen will be necessary, but physically there remains much potential for sophisticated development of this area. Therefore, plans call for further investments in freight handling equipment and the establishment of an industrial zone with the goal of turning this area into a base of distribution of the materials necessary for the economic activities of the surrounding area.

2. The effective functioning of East Harbor is now seriously hindered by its obsolescent and deteriorating facilities. An aggressive program of renovation will be necessary which addresses the technical problems of East Harbor while maintaining harmony with the environment with adjacent downtown Kushiro. It must also address the need for a comfortable "waterfront space" for public use, including open areas for evacuation in case of disaster. Finally, tourist facilities must also be established.

East Kushiro Harbor is the largest fishing harbor in Japan, and much space must be reserved for this essential function.

Fundamentals of a Program for the Redevelopment of East Kushiro Harbor and Zoning Considerations

1. Public and Freight Zone: Renovation aimed at improving the cargo handling capabilities must first be carried out at the conspicuously aging Chuo and Kita Piers; ferry facilities will also be added. A ferry terminal will contribute to attracting tourists, and from this location, feed onto the Fisherman's Wharf area to the east. Furthermore, it will help to tie together the harbor area with the nearby downtown area and function as an evacuation area in case of disaster.

2. Fisheries Promotion Zone: The mooring facilities in Fukuko District and Fishing Pier make up the largest fishing harbor complex in our country and will be further expanded. Also, the facilities for storage and processing and the market just inland from the harbor will be improved.

3. Waterfront Zone: A Waterfront Zone is being planned, incorporating the concepts of Fisherman's Wharf and Riverside Park, the needs of the existing businesses and institutions and the natural scenic beauty of Old Kushiro River.

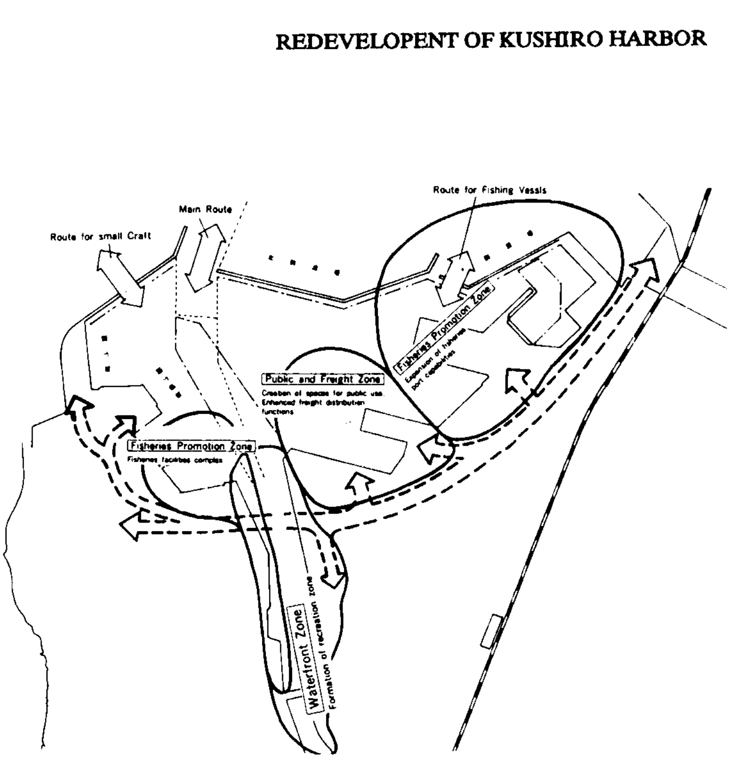

Figure 5. Zoning for redevelopment of Kushiro Harbor, East District

4. Traffic Facilities in the Vicinity of the Harbor: East Kushiro Harbor is served by rather narrow streets and cut in half by Old Kushiro River. The two halves must be better connected by a wellplanned layout of streets and bridges.

The above suggestions are displayed in Figure 5.

A Project in the Redevelopment of Kushiro Harbor

Fisherman's Wharf: The Fisherman's Wharf project is a typical example of the redevelopment going on in East Kushiro Harbor. The project is being constructed along the right shore of the Old Kushiro River by a third sector enterprise, Kushiro Kahan Kaihatsu Kosha. As shown in Figure 6, Fisherman's Wharf is made up of six zones, to be completed in three stages of construction. The first stage has just finished at this writing.

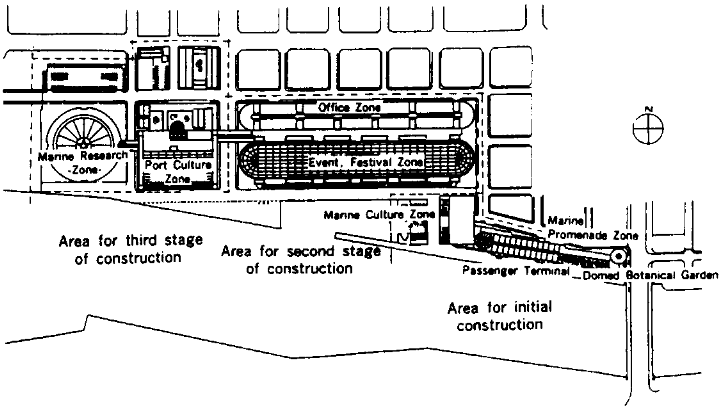

Figure 6. Overview of proposed Fisherman's Wharf facilities

That construction began in 1988, when the domed botanical garden and the passenger ship wharf were completed, and opened in July, 1989. The estimate for visitors was 1 million per year, but usage actually passed 2-1/2 million in the first year, to the delight of the sponsors. The second and third stages of construction are eagerly awaited as further steppingstones to a successful future for Kushiro.

REDEVELOPMENT OF HAKODATE HARBOR

Profile of Hakodate Harbor

As shown in Figure 1, Hakodate stands at the south tip of Hokkaido, near the center of Oshima Peninsula on the shores of an excellent natural harbor. Hakodate has a long and distinguished history as a port since 1859 when, along with Yokohama and Nagasaki, it was designated as a port open to foreign commerce. Construction of a breakwater began in 1910, and both a 900 meter (2952-foot) breakwater and a 950-meter (3116-foot) sand dike were completed in 1918. Improvements were continued; Wakamatsu Pier came into service in 1920 and Arikawa Pier followed in the 1940s. 1969 saw the completion of Kita Pier, 1971, Chuo Pier, and 1973, Bandai Pier. Following the inaugural train passage through the Seikan Tunnel between Aomori (on Honshu Island) and Hakodate in March, 1988, the longstanding ferry service between those two cities was discontinued. The effective use of the area formerly used for the ferry connection and the renovation of the many aging and dilapidated structures back from the shoreline have become hot public issues. Hakodate is designated as a major port, handling 21,740,000 tons of cargo in 1988.

Problems Facing Hakodate Harbor

The most important problems of Hakodate Harbor include adaptation to the increasing size of vessels and the increasing sophistication of cargo management, development of the waterfront, publicizing Hakodate in the international market as a tourist destination, and construction of a moorage for small craft. In addition, preservation of historic harbor structures and promotion of fisheries are problems needing to be addressed. Finally, how to take full advantage of recreational areas and redevelopment of the harbor area is a question which will be answered in development plans.

Fundamentals of a Program for the Redevelopment of Hakodate Harbor and Zoning Considerations

1. The Freight and Production Zone: Some of the water area in front of Kita Pier and Minatomachi district will be filled in and the pier facilities will be upgraded for large-scale foreign cargoes, unit load cargoes and other configurations. Production facilities will also be approved here. In keeping with present operations in the sector from Chuo Pier to Nanaehama Pier, this will be modernized with new cargo handling equipment; the overall emphasis will be on domestic trade.

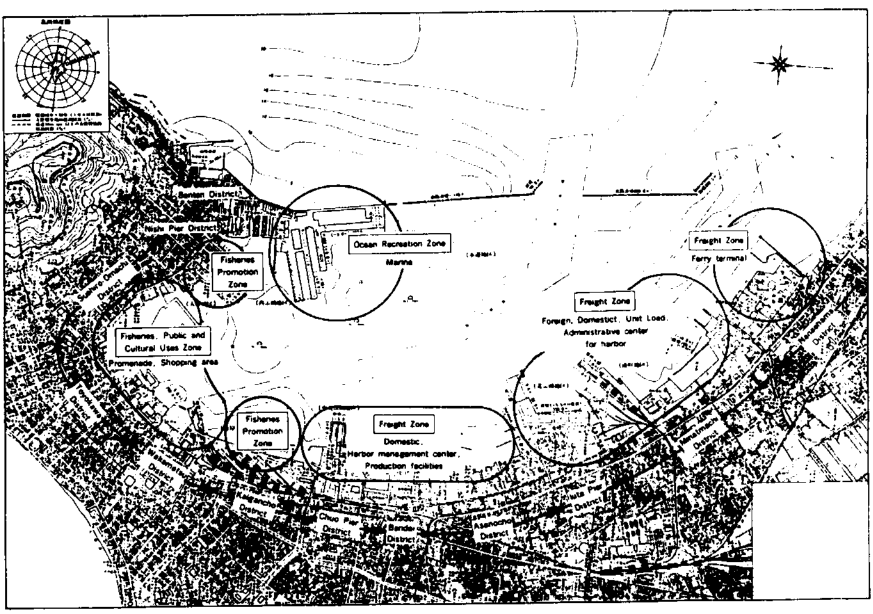

Figure 7. Zoning for redevelopment of Hakodate Harbor

2. Fisheries Promotion Zone: The Nishi Pier District will be further equipped for handling large-scale fishing ships as it has in the past, and with expanded public rest facilities. Kaigancho District will be equipped for small craft moorage, and the fish market and other facilities in Toyokawa District will be upgraded in a fashion compatible with other ongoing waterfront development.

3. Construction of Ocean Recreation Facilities: The remains of the old dock in Benten District and the unused shore here will be developed with a marina, hotels and leisure facilities.

4. Zones for Public and Cultural Uses: The historical and cultural capital of Hakodate in the sector from Omachi District through Wakamatsu District will be used to advantage in new zones here, in harmony with the downtown areas behind. A promenade along the waterfront will allow citizens and visitors to enjoy the spectacle of the harbor, and various facilities will be constructed, including buildings for cultural events, convention centers, a pier for the docking of international passenger ships, and a general terminal for foreign visitors.

Figure 7 outlines the concept for the harbor.

A Project in the Redevelopment of Hakodate Harbor

Pier Market and the Memorial Ship MASHU-MARU: The jetty for the ferry to Aomori (Honshu) and the ferry MASHU-MARU itself did not stand long unused. As these are in a convenient location near Hakodate Station in the historical district of Wakamatsu, the jetty has been renovated into the shopping and dining district "Pier Market," while the ferry has been refurbished as a cultural center and rechristened "the Memorial Ship MASHU-MARU." These were undertaken by Hakodate Seaport Plaza, Ltd. Pier Market opened in July, 1990 and enjoys popularity with Hakodate natives and tourists.

CONCLUSION

This paper has outlined some projects in the ongoing efforts to redevelop the harbors of Otaru, Kushiro and Hakodate with comprehensive designs of "port spaces:" A harmonious blend of freight handling, industry and public/recreational areas. The many considerations during the course of these plans have led to some general conclusions:

1. Up to the present, harbors have been designed with little or no regard for recreational uses of the adjoining waterfront; even when these have been taken into account, they have been limited to a small portion of the total space. It is essential to increase these insufficient facilities in balance with the other functions of a harbor, freight handling and industry.

2. Designers must also give full consideration to the character of the city behind the harbor when planning recreation facilities. Furthermore, in contrast with

cargo loading equipment and factories, which are designed commensurate with the scale of the harbor, the recreational spaces must be designed on a human scale.

3. The routing of traffic flows among the freight handling areas, industrial areas and public areas must assure safety and convenience for all concerned.

4. Aesthetic considerations have seldom, if ever, entered into the design of port facilities. The image of harbors in the public mind as unapproachable, concrete-encased places should be replaced by not only convenient, but attractive designs. Not only will much rebuilding of the presently standing port facilities be necessary, the industrial areas will need to be beautified as well.

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Growing Trends of Port Economic Zones

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ABSTRACT

That the prosperity of a city relies on its port and that the port is utilized by the city is a universal law of the development of coastal port cities all over the world. It is due to the ports that Tianjin Port and Qingdao Port have become Tianjin City and Qingdao City, and that special economic and development zones have been sited in coastal port cities. As the link between home and abroad, coast and inland and international terminal markets, the port develops and flourishes along with the city. Moreover, the general trend of world economy is development and cooperation, thus, this kind of regional economy, with port and city developing in their natural way, needs to be recognized for the development of productive forces. Given this natural link of port and city, the single function port can't allocate the factors of production efficiently, and the comparative advantages of port and city can't establish the coordinate regional relationships in accordance with the development of productive forces. The port only acts as the locational centre of regional economy, a conduit for the passage of economic flow, such as that of goods, people and information. It has not been transformed by its locational advantage for commodity production.The discussions here on commodity production and the multi-functions of ports will, I hope, provide some evidence for the port-land economic plate theory, or even for a new theory of port economics.

International Perspectives on Coastal Ocean Space Utilization
Phyllis M. Grifman and James A. Fawcett, Editors

ESSENTIAL FEATURES OF PORT ECONOMIC ZONES

Several Models of the Expansion of Productive Forces in Port Cities

After transforming a port into a city, the port has further developed. Generally speaking, under the restriction of civic scale and its productive forces there are three outlets for the development of an urban port economy in order to increase the handling capacity of the old port, with a consideration of the spatial distribution of productive forces.

First, rebuild and extend the old port. In other words, if the port has a deep water front, the industries in the central position of urban economy can be moved or expanded to neighbouring areas, such as has been done in Singapore and Shanghai Port. Its disadvantage is that the scale of the city is larger and larger, and that the distribution of productive forces is liable to be inharmonious, and also that the population reaches the saturation point, which makes the regional economy more dependent on the central city.

Second, choose a new port near the old port city to develop a new economic zone. From the aspect of planning, this kind of transforming of productive forces can make it easier to achieve the strategic aim of regional economic development. Its development relies on the various functional zones and new industries near the new port. The investment for the port and for the infrastructure on land are coordinated and its economic development is adapted to the general scale of the region. We can see examples of this kind from Hamburg Port, New Orleans Port and Qianwan Port, which is being set up at present.

Third, satellite port towns or port town groups can be set up far from the central city if the conditions near the old port and city are not fit for opening up a new port. These coastal port towns, called "associated ports" take the old port city as their centre. The Associated British Ports are composed of nineteen ports with annual handling capacity of 100 million tons, which occupy one-fourth of the British trade volume. These ports serve as container terminals, berths for coal, oil, ships, steel, wood, etc. Moreover, the bases for export processing industry, petrochemical industry, machinery and steel industry are set up near the relevant ports. Therefore, the central port regards the satellite ports as its berths or ports of transhipment. This kind of distribution of port groups or associated ports has a high density, reasonable planning and distributing, high efficiency which helps the spreading to inland. However, like Shanghai as its centre, the port groups in China haven't formed a united administrative organization so they can't bring the advantages of each port into full play. Their economic combination is only a loose regional one so that the administrative division and the economic division are not coordinated.

Three Models of Port Economic Zones in China

Many economic and technological development zones, export processing zones, scientific and technological industrial zones and bonded zones have been set up in the fourteen coastal open cities of China. The types of ports are decided by the city conditions, financial resources, economic and material bases, industry, science and education, potential for developing, geographical location, hinterland conditions, and the degree and opportunity of opening to the outside world. Under such conditions, we can only set up fourteen port cities near the ports. For those which lack industrial bases or scientific forces, we can only set up export processing zones as the transition for industrialized port economic zones. For those with good conditions, such as Shanghai, Tianjin, Qingdao and Dalian, we can set up multi-purpose port economic zones.

Export Processing Port Economic Zones

The coastal cities of China, Qinhuangdao, Yantai, Lianyungang, Nantong, Ningbo, Fuzhou, Zhanjiang and Beihai, have sufficient hinterland resources and labour resources. However, science and education in these port cities are not advanced. Therefore, it is appropriate for them to set up port economic zones of material processing, intensive labour and export processing industries.

Trade Port Economic Zones

Guangzhou, Xiamen and Shenzhen are located in the south of China and used to be important commercial ports, with good conditions for trade. Trade, at present or in the future, is or will be the catalytic promoter for the economic development of the port economic zones in these cities.

Multi-purpose Port Economic Zones

The four port cities, Dalian, Tianjin, Shanghai and Qingdao, on which the development zones depend, own all sorts of industries with good bases, many universities and colleges, strong research forces and people of high quality. Therefore, on the basis of development zones, it is appropriate to set up high-tech industrial zones and export processing zones which will be the constituents of high standard, multi-purpose port economic zones together with the ports.

Trade Port Economic Zone	Export Processing Port Economic Zones	Multi-purpose Port Economic Zones
Guangzhou Shenzhen Xiamen	Quinhuangdao Fuzhou Yantai Zhangjiang Lianyungang Nantong Beihai Ningho Wenzhou	Dalian Tianjin Quingdao Shanghai

Figure 1. General Survey of the Open Coastal Cities in China

ESSENTIAL FEATURES OF PORT ECONOMY

Although there are no authorized port economic zones in China, the name "port economic zone" has been used in many occasions. However it must be pointed out that port economic zones are different not only from the administrative district of ports and port cities but also from the economic district of economic and technological development zones, export processing zones and scientific and technological industrial zones and also from free ports.

Port Economy Falls into the Category of Regional Economy

As we know: a regional economy is defined as a certain spatial distribution of productive forces. Port economies fall into the category of regional economies with the typical features of, depending on the port, the best location for developing an export-oriented economy. If a regional economy is under an administrative jurisdiction, it is liable to form a closed economic structure, with which one department in the region excludes another. The typical feature of the closed economic structure is that it protects the backward, excludes outside competition and holds back technological improvements. We can see examples of this from the contradiction between development zones and their administrative divisions during the five-year construction. These artificially imposed obstacles have been weakening the function of preferential policies for the development zones. Overlapping administrative and economic divisions, distortion of the limits of authorities, regulation of "one region, one government" and the separation between a region and its port, all of these have weakened the advantages of port and land locations.

Only by connecting with a commodity economy can a regional economy break the bounds of regions and departments, realize lateral and vertical economic unification and set up the reasonable relationship of cooperation based on division of labour.

Therefore, the port economic zone should be the economic region which is a unity of port and neighbouring land and space connected by a commodity economy.

Essential Features of Port Economy

a. Port as the Centre

Each port is the evident location of the port economic zone and is one of the main characteristics different from other economic zones. A port is not only the decisive factor for the regional economy, but the pivot of developing export-oriented economy in coastal countries, regions and cities. The special economic structure of port economic zones is due just to the existence of ports.

b. Development Zones as the Leading Force

Fourteen economic and technological development zones have been set up in China where preferential policies are offered. The policies offered are basically similar to those of free ports over the world. Our government will have supplied five billion yuan for infrastructure installation in development zones by the end of the seventh five-year plan. Together with the funds raised by the cities themselves, over ten billion yuan has been invested in the development zones. After five-year construction, the development zones have been transformed from blood-transfusing economies to blood-forming economies. Foreign capital has been invested to the tune of two billion dollars in about 1,000 Sino-foreign joint ventures. Sino-foreign joint ventures, Sino-foreign cooperative enterprises and exclusively foreign owned enterprises have been registered. It is estimated that the industrial output of the development zones will reach 10 billion yuan in 1990. Besides, on the basis of development zones, some export-processing zones, scientific and technological industrial zones, bonded zones and tax-free storehouses have been set up, which have become the leading force for the port economic zones to develop an export-oriented economy. Only through international cooperation and competition and opening to the outside world can any nation or region develop rapidly.

Integration of the Port and Region in Administration

The administrative system is the difficult point for the integration of port and region. We must break the bonds of administrative economic divisions and break free from the conventions "one region, one government" so that the administrative district, port and development zone can be united into an economic district. In this way centralized management can be realized so that coordinated development will be possible. The administrative organ of the economic zone should be highly efficient and free from corruption. For the purpose of harmonizing the relationships it is appropriate that the leader of the region holds an authoritative position over the port economic zone.

GENERAL DEVELOPING TRENDS OF PORT ECONOMIC ZONES

Developing Features of Port Cities

Just as the name implies, port city is composed of port and city, which, being interdependent, help each other forward. The prosperity of the port relies on the port, the port is used for the city, port and city flourish together shows us the relationship between them. No matter what kind of administrative relationship exists between port and city, the economic connection should be, first, the systematic combination of productive factors, especially the structural coordination, and secondly the combinaton of organizational affiliation. According to location theory, the port is the central location of a port city economy, and the best location in all the open systems as well. Ports, as the central location of the regional economy can make the economic factors of production such as location, rate of passage, labour, price, trade, industrial structure and scale, reach their best allocative points. The centre of port location has the following changes by reason of the mode of production and of administrative system:

a. Due to administrative intervention and restriction the importance of port location contains economic factors and social factors as well;

b. With the reform and opening of China, special policies have been offered for ports, which makes the location centre develop in a multi-functional way;

c. With scientific and technological progress the industrial structure makes internal relations between port and city more inseperable and complicated so that unification of port and land can be strengthened.

In several port cities of China, because of the seperation of administrative divisions and ports, the functions of ports are not brought into full play. Consequently, port economy and land economy are separated. The port only serves as the transport passage. The general developing plan of regional economies and that of ports are made from two separate directory channels, and the construction funds come from two resource channels as well. Port and city are relatively closed so that it is very difficult for allocation of the productive factors in the two locations to reach the optimum.

Small Gradient Structure of Port Economic Zones

Since the Open Policy was carried out in China, the setting up of special economic zones and economic and technological development zones and the opening of the fourteen coastal port cities as well, have formed a small district gradient structure between port, city and development zones. (Figure 2) Consequently the function of ports has changed qualitatively. The trend of this change is still in its embryonic stage, but the level and energy for the productive forces and exchange of commodities, between port and city, and home and abroad markets, grows. Taking the port as its centre, the development zone as its lead and relying on the port city, the new port economic zone has been emerging. Therefore, new functions and new features will be added to the economy of the port city.

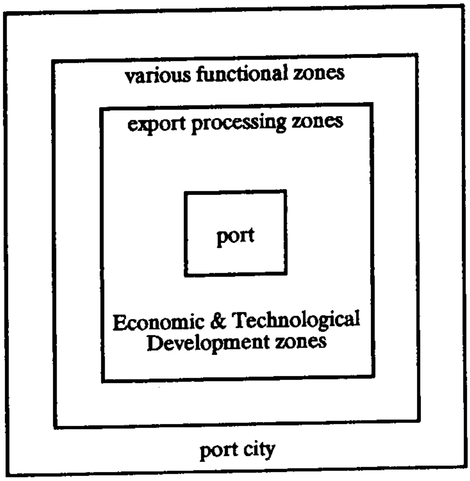

Figure 2. Port District Gradient Structure

Note: various functional zones include scientific and technological industrial zones, travelling zones, bonded zones, etc.

A. Port, tie of the export-oriented economic regions, is transforming to a multi-functional one.

For the purpose of making use of the port — the bridge connecting the international terminal market — most of the economic and technological development zones, export processing zones, bonded zones and scientific and technological industrial zones have been set up near the ports, so that port and land can be united into an economic plate.

Therefore, ports will be transformed from the single function of transportation to the comprehensive multi-functions of commodity flowing, foreign trade, transfer industrial processing storage, insurance, finance and services.

B. New Feature

With the port-land economic plate, the advanced industrial structure of productive factors and the allocative structure of near hinterland resources will be the motive force for the economic development of port economic zones.

Besides administrative intervention, the decisive motive factors for setting up a new port economic zone are the standard of development and features of productive forces. With improvement of the ability to participate in international economic cooperation and competition export-oriented port economic zones will be part of the international market. Therefore it is as if the hinterland commodities enter the international terminal market as they come into the port economic zones. In order to reach the standard stated above, cooperation and connection between the functional zones must be close. The technical industries in the last twenty years of this century have transformed traditional industries with a result of overlapping between industries which makes conflict between the functional zones closer. In this way, the single industrial separatist structutre can be changed so that the economy of the port economic zones will be pushed forward.

C. New Trend

After ten years' practice since the special economic zones and development zones were set up, the contradiction between administrative divisions and economic divisions and the evils of the system have been shown. So it is likely that the port economy is identified by the national authorities.

Consequently, in the transitional period for free ports, several port economic zones will be set up estimated in 1995. The present international trend is to develop cooperation. Therefore, as the outposts of reform and opendoor policy, port cities and development zones will certainly participate in the international competition and cooperation as their one of the most important aims.

General Developing Trend of Port Economy

The first leap of the Chinese port economy is to set up "port economic zones," that is, to integrate the ports, development zones and administrative districts, so that productive forces can develop in bigger space to reach the optimized industrial structure. What it needs to change is the administrative system of port and district. Two steps can be taken: first, development zones unite with the administrative districts, that is, to unite the administrative and economic divisions. Second, port and divisions are united for planning. In this way, it is possible to set up a port economic zone in 1995.

The second leap of the Chinese port economy is to set up free ports or free ports with Chinese characteristics, which is likely in the next century.

(Edited by P.M. Grifman)

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Can a Proposed Marina Be Linked to Wetlands Restoration? Planning at Marina del Rey and Ballona Wetlands, California

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ABSTRACT

Marina del Rey, the largest man-made marina in the world, was constructed on degraded wetlands of the former Ballona Estuary in 1960-1962. Ballona Creek, which drains much of western and northern urban Los Angeles, was concretized in the 1930s as a flood control measure, largely cutting off tidal access to the wetlands.

Development of a large residential, recreational and commercial complex, Playa Vista, is planned on the uplands adjacent to the existing Marina del Rey, on a contiguous abandoned airport site, and on the remaining Ballona wetlands. Planning now includes restoration of those remaining wetlands to a half tidal or full tidal cycle inundation, construction of a freshwater pond, and addition of a new marina area connected to the existing Marina del Rey.

The new marina will require a modification of the Local Coastal Plan. Marine scientists have participated in design of wetlands restoration and the new marina, leading to a concept of linking the marina with the wetlands hydrologically through Ballona Creek, and to designing new substrates to enhance the marina as a habitat.

Marina del Rey was monitored by the Harbors Environmental Projects of the University of Southern California during baseline studies in 1976-1979 and continuing in 1984-1991. Results showed that the artificially created marina served as a habitat at various times for all but about six species of fish found in natural southern California estuaries, indicating its value as a resource, although populations are not high. Linking the areas hydrologically and improving design of substrates could substantially improve the biological quality of the marina areas and the wetlands.

International Perspectives on Coastal Ocean Space Utilization
Phyllis M. Grifman and James A. Fawcett, Editors

HISTORIC BALLONA WETLANDS

At the turn of the century much of the coastline of what is now Los Angeles and Orange Counties was wetlands. Ballona Creek, which flows west into Santa Monica Bay, extended far inland on the north of the Palos Verdes Peninsula, where ponds and sloughs merged with those that drained into the Los Angeles River watercourses on the south coast. At times the Los Angeles River changed course to exit through Ballona Creek while Rio Hondo flowed through the channel now occupied by the Los Angeles River. A typical barrier beach existed, with Ballona Lagoon behind and parallel to it to the north and the present Del Rey Lagoon to the south.

The Ballona area, site of Marina del Rey, was several times considered for development as the major port for the growing city of Los Angeles, competing with the Los Angeles River mouth for funding. The latter was selected because it presented a more protected exposure, but politics among the early day railroad tycoons played a large part in decisions.[1,2] Proposals were also made to link the two areas hydrologically, which would have been relatively easy until the explosive post World War II development of the southern Los Angeles Basin. Figure 1 illustrates the wetlands in the greater Los Angeles area in 1901.

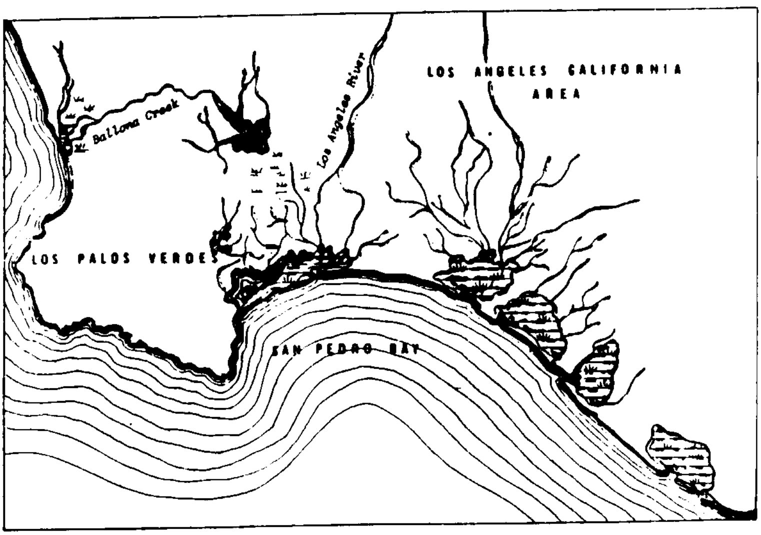

Figure 1. Coastal wetlands of the greater Los Angeles area in 1901

Postwar population increases also brought increased popularity to the small boat industry and, concomitantly, demand for marinas and ancillary facilities. Ballona wetlands had become seriously degraded before and during World War II. They had formerly extended inland to the area near the present day San Diego Freeway on the east, and from the Venice area on the north southward through the village of Machado, a stop on the Santa Monica Railroad (later the Pacific Electric Railway) to the port of La Ballona. The area had been filled with earth and rubbish in a patchwork to form industrial plant sites, an airport runway, oil, gas well and roadway berms and farmlands, while irregular furrows and small drainage channels had formed to carry runoff. Public health concerns over mosquito and black midge populations favored drainage as a measure of ameliorating the nuisance, without any real appreciation for the beneficial roles that wetlands play as an ecosystem.

Rivers and creeks of the Los Angeles Basin were channeled and concreted in the 1920s and 1930s to control the massive floods that occurred during heavy winter rainfall, incurring deaths and severe damage to homes, businesses and port facilities. Ballona Creek became a Los Angeles County Flood Control Channel, with concrete walls cutting off tidal circulation to the wetlands. Tide gates led to the Del Rey lagoon on the south side of the channel and on the north side to Ballona Lagoon, which feeds the Venice Canal system. A few openings to the wetlands on the south side inland of Playa del Rey were soon blocked shut to protect gas storage well heads and roadways from flooding.[3]

CONSTRUCTION OF MARINA DEL REY

Construction of Marina del Rey in Los Angeles County took place in 1960-1962 by draining the wetlands on the north side of Ballona Creek Channel, building dry land walls and basins, and then dredging the channels to the ocean.[4] Design of the Marina, with the Main Channel angled away from the Entrance Channel and with Basins A through H branching off the Main Channel on either side, was supposedly to provide adequate protection from storm waves and surge. While a physical model of the proposed Marina had been built at the Army Corps of Engineers Waterways Experiment Station in Vicksburg, Mississippi, this did not ensure against vulnerability. Soon after Basin A was occupied a winter storm reflected off the east wall at the junction of the inner Entrance Channel and Main Channel, across the channel into Basins A and B (Figure 2), incurring severe damage. Thus a breakwater had to be constructed as well.

Plans have for many years included adding another Marina basin near the Entrance Channel off the Main Channel and one such configuration is provided in the Local Coastal Plan (Figure 2). Ownership of that site has been in private hands, controlled by the Hughes Summa Corporation interests until recently, when Maguire Thomas Partners assumed control of the Hughes Ballona holdings, including the remaining wetlands. Since Los Angeles County does not own the land, it could not be developed with public funds as Marina del Rey was.

ENVIRONMENT OF THE EXISTING MARINA

It is possible in retrospect to think that the original marina project would not have been permitted a decade or two later because of the public's changing perceptions of environmental impacts. At the time of construction, however, the habitat values of wetlands were largely not appreciated, especially in regard to their linkage with productivity of coastal fish populations. The change from large areas of tidally flushed sand and mudflats to channels with straight sided, concrete walls and silty bottoms changed and decreased the indigenous biota greatly.

Certainly at the time of Marina construction the objective of calm waters to protect small craft was paramount over maintenance of water quality and habitat values, and construction of the breakwater further reduced the low level of circulation and flushing.

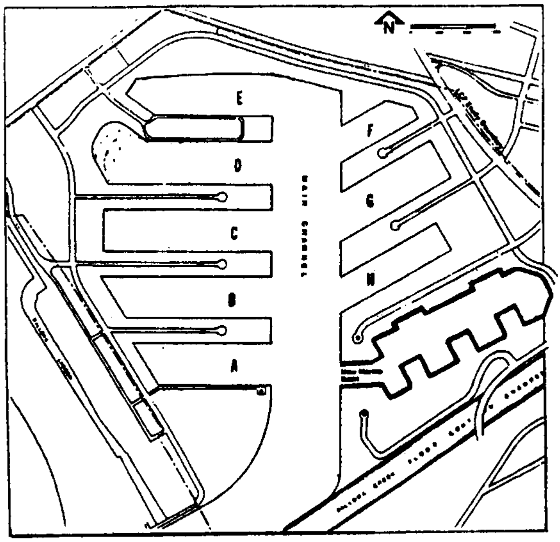

Figure 2. Marina del Rey and a proposed new basin, based on the Local Coastal Plan.

Environmental Studies

No biological baseline studies were performed before or immediately after construction of the Marina. Physical variables were studied in the early 1970s,[5, 6, 7] and a marine biological, chemical and physical baseline was conducted by Harbors Environmental Projects (HEP) of the University of Southern California (USC) from July 1976 to June 1979 under joint funding by the Los Angeles County Department of Small Craft Harbors (now Beaches and Harbors) and the USC Sea Grant Program.[8, 9]

Following a hiatus of five years, a new series of surveys was undertaken in 1984 by HEP, varying from one to two quarters a year until October 1988, when monthly surveys were resumed for water quality, while fish surveys and benthic sampling for biota and sediment chemistry are conducted semiannually (Figure 3). Special studies have included bioassays examining the effects on selected indigenous species of contaminated Marina sediments and the highly toxic antifouling substance tributyltin, sources of enteric bacterial contamination, and body burdens of polychlorinated biphenyls and DDTs in Marina fishes, especially those caught for consumption at the public fishing dock.[3,4,10,11,12,13]

Results of these studies have permitted a number of conclusions to be drawn about the quality of the Marina as a shallow water habitat and hypotheses generated concerning ways to improve the productivity of both the new marina and the wetlands without sacrificing the recreational function of the new marina.

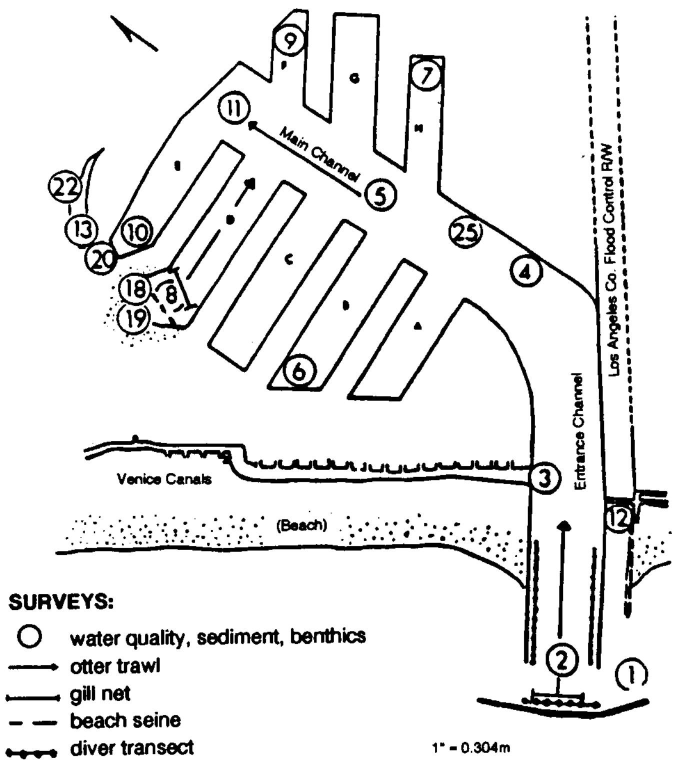

Figure 3. Survey stations in Marina del Rey. Circles represent monthly water quality stations and semiannual benthic fauna and chemistry stations; fish surveys are indicated by method.

Fish Resources

Fish surveys, conducted since 1984 in May and October in cooperation with Dr. John S. Stephens, Jr. and his Occidental College (Los Angeles) Vantuna Research Group, have included otter trawls, gill netting, ichthyoplankton tows, beach seines in Basin D, and diver surveys (Figure 3). The number of species has been high, about 95 taxa, with an average of about 40 species present during any single survey. These species represent some widely ranging coastal species and some with more restricted ranges; some are present in cooler water years and some in warmer water years. More importantly, they include all but a few of the species found in local natural estuaries, such as Upper Newport Bay, habitats that have been heavily impacted by urban development and are constantly threatened by contamination.[14]

Fish populations vary greatly, depending largely on the number of pelagic smelt that school at any given time in Basin D in the Marina, feeding in the seagrass bed there. Eggs, which may be shed in the Marina or carried in on the tides, and larval or juvenile fish thrive in spring and fall in the warm waters which contain high densities of phytoplankton and microheterotrophs for food. Turbidity gives the smallest fish some measure of protection from predators. Because the Marina basins are shallow (about 4 meters) and the circulation reduced, summertime may find the waters too warm, occasionally with low dissolved oxygen, for resident fish to remain, causing them to move out of the Marina into cooler, deeper waters.

The Marina would be more productive if the water and sediment contaminants could be reduced, and if the intertidal substrate were rocky and irregular rather than being primarily composed of straight vertical L shaped walls.

Benthic Fauna

Benthic species are good indicators of environmental quality since their mobility is reduced or restricted to larval stages and they cannot escape from an inhospitable environment as can most fish species.

The benthic fauna of a saltwater wetlands, with very fine grained sediments such as those found in the Marina, would normally consist largely of polycheate worms, molluscs, crustaceans and echinoderms. Contaminated sediments tend to favor the less sensitive polycheate species and select against the more sensitive molluscs, crustaceans and echinoderms, as has been the case in the Marina. There is relatively little rocky intertidal habitat present which would support larger crustaceans, however.

Benthic populations vary with the distance from the Marina entrance, tending to have more diversity and higher populations in the outer areas than in the inner Main Channel and the basins. The poorest area is at the end of the Main Channel where new slips were constructed a few years ago.

ENVIRONMENTAL IMPACTS

Impacts Originating in the Marina

The Marina is subjected to a variety of environmental insults, most of which originate outside the Marina. While users of the Marina are responsible for some oil and gas in the water, trash, illegal disposal of cleaning agents such as detergents and sodium hypochlorite, and illegal emission of fecal bacteria, the residents and visitors for the most part seem to be restrained in polluting their own habitat.

Antifouling compounds have, however, a considerable impact on the biota, since they are not as selective as would be desirable. Tributyltin (TBT), an antifouling paint additive now banned on most recreational vessels, was one of the most harmful substances to which biota were ever exposed, especially in the ablative paints that emitted an almost constant flow for the life of the paint. Mollusc, crustacean and fish larvae are sensitive to concentrations in the parts per trillion range.[3,12,15] Although direct statistical evidence is not available, the banning of TBT containing paints by California in 1987 appears to have had an effect on return of *Mytilus* (mussels) populations and intertidal crabs, which had virtually disappeared from the Marina.

Impacts from Outside the Marina

When the Marina was designed, storm drains were located at the ends of the basins, with the thought that rainfall runoff would help to flush the Marina. Unfortunately, the drains also wash street and parking lot pollutants into the Marina; in periods of low rainfall, contaminated sediments tend to be carried into the Main Channel or become deposited at the sand bar in the Entrance Channel, adding to the pollutant burden of the Marina. Restaurants have been known to wash grills and dump grease into storm drains as well, and fecal contamination from pets and transients may occur.

Ballona Creek Flood Control Channel drains a large area of the northwestern Los Angeles Basin into Santa Monica Bay. It has a low dry weather flow, but in rainy seasons brings downstream street and industrial site runoff, and illegally disposed pesticides, garden debris and plastic food wrappings in large quantities. Some of this storm flow is reflected off the breakwater into Marina del Rey or is brought in on subsequent incoming tides. A City of Los Angeles sewage facility has an emergency overflow into Ballona Creek which has, in the past, released large quantities of liquid. The chief hazard to marine organisms is the emergency dumping of chlorine on such occasions for protection of public health; chlorine is extremely toxic to organisms. Maximum high tides can also wash much debris off the riprap of the Channel because fishermen spend the day near the ends, without sanitary or trash facilities, and dogs are often exercised along the walkway and rocks.

Oxford Flood Control Basin, euphemistically called a bird sanctuary on planning maps, receives drainage from a smaller area of residential, commercial and industrial land along the periphery of the Marina. It seems to receive very high loads of heavy metals and pesticides, and is in fact usually the most contaminated site of those tested in our Marina surveys. It also is contaminated with fecal bacteria; for some years pet chickens, ducks and rabbits were abandoned there, mixing with a few wild or feral animals, until vegetation was stripped and banks eroded. Removal and restoration efforts controlled that, but the area still carries a higher level of fecal bacteria than should be draining into the Marina.

Problems of high fecal bacterial counts were discovered during testing by the Los Angeles County Department of Public Health in Basin D, the only beach in the Marina, following a sewage plant breakdown elsewhere. A search for sources such as leaking sewer lines was negative and the search was narrowed to focus on the large seagull population that rested or roosted on the beach, particularly during low visitor usage periods.

Sediment and Water Quality

It was found that the Marina was more heavily impacted by events that originated outside the Marina than those associated with Marina uses. Dry weather flow in Ballona Creek brings large amounts of illegally dumped trash such as yard debris, pesticides and plastic containers down the channel, and wet weather flows, which drain from a large portion of northwest Los Angeles, flush streets of oil and grease and accumulated trace metals.

Statistical analyses of trace metals and pesticides indicated that no single parameter was directly correlated with the incidence of benthic fauna. Bioassay tests of sediments from the various stations with mixtures of contaminants using representative indigenous benthic polycheate worms, mussels and fish indicated that the sediments were not acutely toxic, but there was depression of reproduction during long term tests, in both water and sediments from the most polluted stations.[12]

THE MARINA AS A WETLANDS RESOURCE

In spite of the environmental problems originating from within and without in the Marina, it serves as a valuable habitat in a region that has lost more than 90 percent of its natural, sheltered, shallow water habitats.[17] Some 90 taxa of fish have been recorded over the USC survey periods by various sampling techniques, indicating that the area hosts a wide spectrum of larval, juvenile and adult fish. An average of 40 species are present at any survey period, but the species vary according to water temperature and season.

The calm, turbid waters, with an ample supply of phytoplankton and bacteria for food, provide protection during the early growth period, after which some species move to cooler, deeper waters. Twelve species have been found in all surveys since 1984, one of which, the striped mullet, is uncommon in the Southern California Bight. Schools of smelt, important forage fish, feed in the seagrass bed off the sand beach in Basin D.

While the benthic fauna are little different from those in similar silty bottom areas, the large numbers in some areas of the Marina provide food for demersal fish. The relatively small area of rocky slopes in the Marina, limited mostly to the riprap of the Entrance Channel, reduce the potential habitat for a number of species that might otherwise occur there, or might occur in greater numbers.

DESIGN OF THE MARINA EXPANSION FOR ENVIRONMENTAL CONCERNS

Configuration

While the primary purpose for Marina expansion is to accommodate larger recreational boats, and the economics of such a large project dictates that maximum use of the space available be made, experience with the existing Marina indicates that environmental concerns can also be addressed to some extent. The configuration proposed in the LCP (Figure 2) was tested by a physical model and confirmed the scientists' conclusions that circulation would be very poor, leading to unacceptable flushing rates and probably dissolved oxygen levels too low to support fish life. This also renders the area unpleasant to recreational users, producing odors and possibly damaging vessels with sulfide from anoxic waters.

A subsequent preliminary design by Moffatt & Nichol Engineers eliminated fixed finger slips with floating docks and central islands, improving circulation, but a lagoon was added at the inner end (Figure 4). While this was discussed as a fish habitat similar to the beach area in Basin D, public agencies decreed that it is supposed to receive runoff presently directed into Basin H, which would negate the habitat values by introducing contaminated, high volume, low salinity runoff in rainy weather and contaminated, low volume, dry weather flow. In effect, it was to serve as an oxidation pond. In comparison, Basin D receives very little runoff and hence supports the seagrass beds that require marine salinities.

Further physical and theoretical modeling indicates that the lagoon configuration would have unacceptably low flushing, resulting in low dissolved oxygen. There will no doubt be several revisions to designs before final configuration is achieved. It is possible that the various objectives of providing adequate flushing, diversion/oxidation of runoff, flood control, and also providing fish habitat are mutually exclusive.

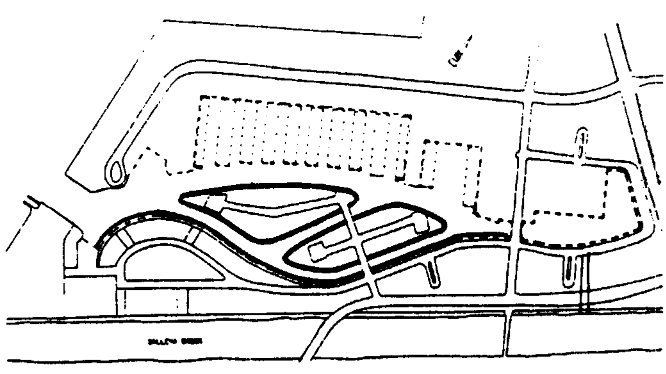

Figure 4. One proposed modification plan of the marina addition

Wall Construction

The existing Marina was built of traditional L-wall construction, with smooth sided walls and no intertidal rocky areas, which does not offer habitat niches preferred or required by some invertebrate and fish species. Some crustaceans and molluscs need a crawl-out area partially above the high tide marks, and some fish need the shelter of the rocks and shallow water which also support small biota needed for food.

A number of scientists were invited to confer with Maguire Thomas Partners, Playa Vista (MTP-PV), the developers, to determine how construction could maximize the new marina as a habitat. Habitat values were calculated by Moffatt & Nichol for a variety of wall constructions, ranging from the L-wall (Figure 5), through low and high mud slopes to rocky revetments (Figure 6), a mixed slope (Figure 7) and a so-called bio-wall with gravelfilled boxes fixed to the sides to provide reproduction area for certain fish species.

Mud slopes were the most productive but were considered not economically feasible because they would require too much width to support the walls, taking space urgently needed for vessels, and because of stability problems. The rocky revetment also requires a great deal of space, and the bio-wall, while not requiring much space, had a lower value than the L-wall over all, although it might be best for particular fish species. A mixed slope wall, constructed with gabions or small stones, has about the same habitat value as the rocky revetment and required slightly less space. The space required and the habitat values calculated are summarized in Table 1.

LINKAGE WITH WETLANDS

Construction of the new Playa Vista Marina and mixed residential and commercial community was delayed by lawsuits brought by Friends of Ballona Wetlands against Hughes Summa Corporation, to prevent development of Ballona Wetlands, on the south side of Ballona Creek. Settlement with the Hughes successor, MTP-PV, precluded high density development or golf course construction on former wetlands, and sale of some State property (Figure 8) in exchange for an agreement by MTP-PV to restore 269 acres of former and remaining wetlands to at least half tidal cycle flooding.[18]

While wetlands restoration has been attempted in several locations in southern California, with mixed success, the fact that the wetlands tidal channels are still largely intact and soils have not been seriously dislocated gives confidence that restoration of at least partial tidal flushing and reintroduction by planting of wetlands flora will markedly improve that habitat.

This is not an inconsiderable endeavor because existing roadways and gas wells must have berms raised to protect against flooding. Also, an endowment fund must be made available to maintain the wetlands once it has been restored.

Restoration of full tidal flushing would be much more productive, offering habitat for rare, threatened and endangered bird and plant species, and much more room for development of the eggs, larvae and juveniles of estuarine fish species, whose habitats have been so drastically reduced in southern California.

Scientists have recommended that, because the existing Marina del Rey has been demonstrated to be a habitat for many fish species, the new marina and the wetlands be linked by flow between the two areas through Ballona Creek. A conceptual scheme linking the two areas is shown in Figure 9.

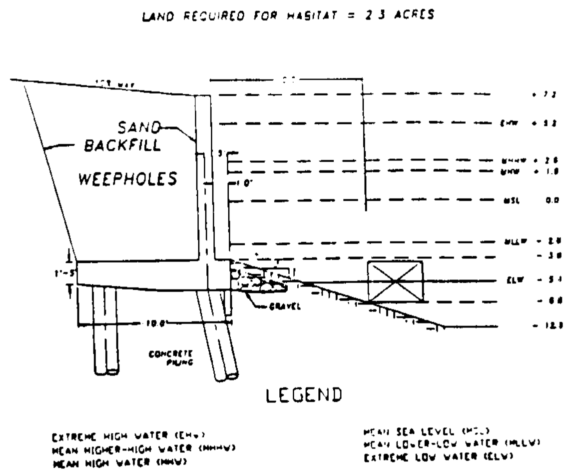

Figure 5. Traditional L wall construction (Moffatt & Nichol)

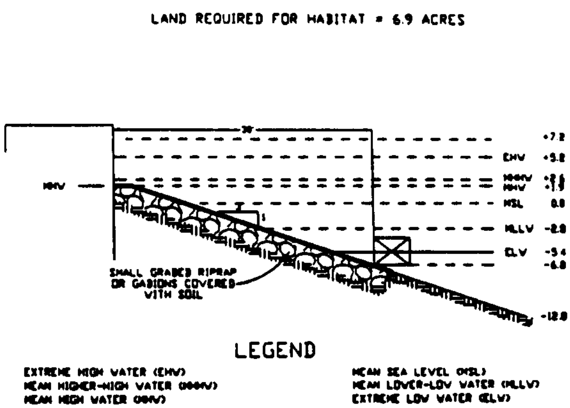

Figure 6. Rocky revetment (Moffatt & Nichol)

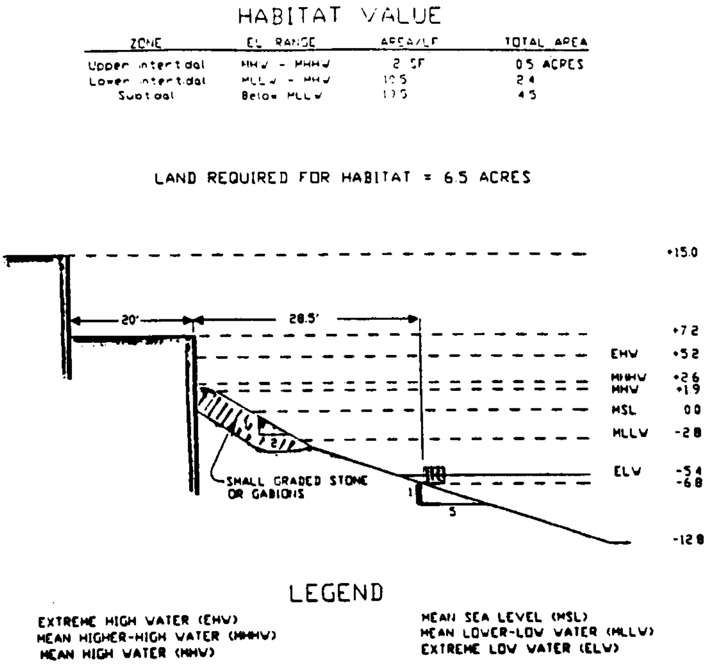

Figure 7. Mixed slope perimeter (Moffatt & Nichol)

Table 1

Summary of Habitat Values Calculated for Various Designs for Playa Vista Wall Construction (Moffatt & Nichol)

		HABITAT AREA (ACRES)			
Wall	**Offset (Feet)**	**Upper Intertidal**	**Lower Intertidal**	**Subtidal**	**Total**
Traditional L-Wall	10	0	0	2.4	2.4
Rock Revetment	30	0.9	3.4	2.9	7.2
Low Mud Slope	24	0	0.9	4.7	5.6
Mud Slope	43.5	0	5.5	4.7	10.2
High Mud Slope	47	0.8	5.5	4.7	11.0
Mixed Slope	28.5	0.5	2.4	4.5	7.4
Bio-Wall	10	2.3	0	0	2.3

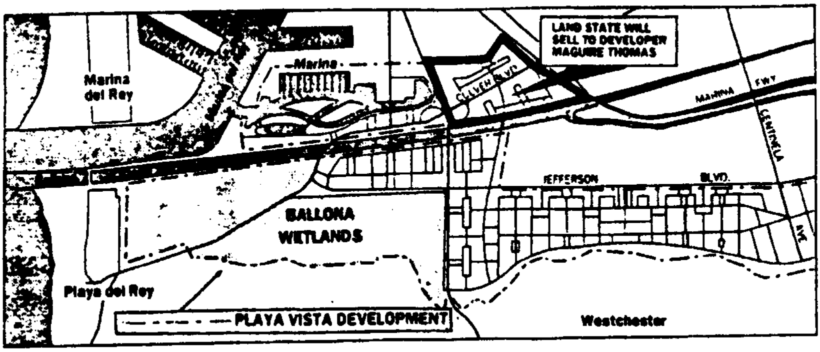

Figure 8. Playa Vista development (Los Angeles Times, 14 September 1990)

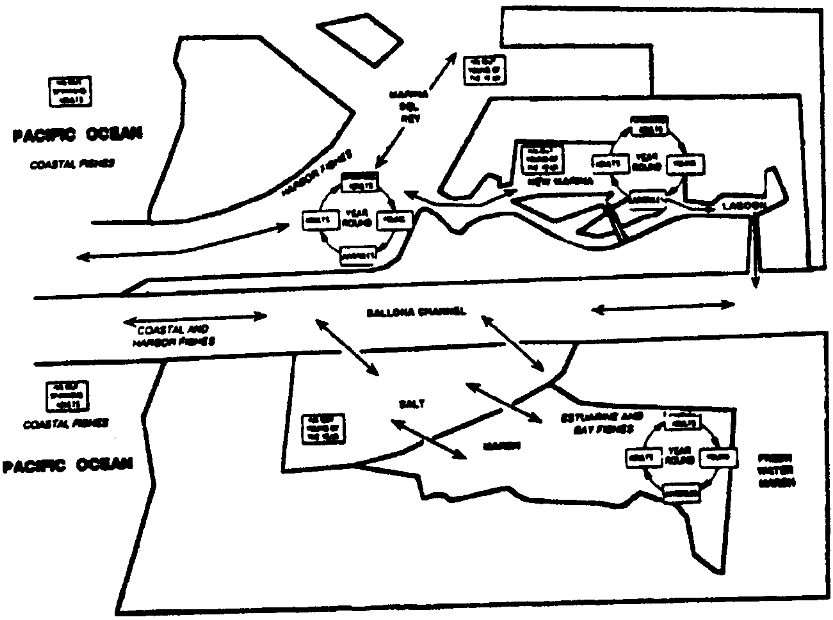

Figure 9. Conceptual relationships linking existing Marina del Rey and the new marina with Ballona Wetlands (after Davis, 1991)

Such a plan would require regrading of the outer end of Ballona Creek to eliminate a sandbar upstream, reconstruction of some street overpasses or rerouting, and hydraulically linking the two water areas with flow from the Marina to the wetlands, maintaining a minimal water level in the creek bed during the lowest tides.

Additional funds must be found for this extensive construction outside of the MTP-PV settlement. The Ports of Los Angeles and Long Beach are currently seeking areas for mitigation of habitat value losses that will occur when the ports proceed with development of their master plan, the 2020 Plan, to fill a large area in outer Los Angeles Harbor. Regulatory agencies require mitigation of these impacts, potentially by restoration of shallow water habitats in southern California, and the Ballona Wetlands restoration is a candidate for such funding.

Davis calculates that a restoration with full tidal range would have a habitat value on an acre-for-acre basis five times as high as that in the area being lost in the ports.[19] Full tidal height restoration is estimated to be three times more valuable than the half tidal height agreed to by the MTP-PV settlement.

CONCLUSIONS

The question posed in the title "Can a proposed marina be linked to wetlands restoration?" may be answered in several ways. Physically, linking existing Marina del Rey with the proposed Playa Vista Marina, Ballona Creek and the restored Ballona Wetlands is possible and feasible from a topographic and hydrologic point of view.

A number of ecological benefits could accrue, such as: offering a greater variety of contiguous substrates which would support a greater variety of biota on which larger organisms feed; more opportunity for changing habitat niches as life stages of organisms change; more opportunity for moving between shallow water and deeper water as temperature and salinity vary; better distribution of nutrients; and better water quality due to stabilization/sequestering of contaminants in runoff waters.

Many lessons have been learned in wetlands restoration in recent years, one of which is that if original wetlands soils and contours are present, there is a much greater chance that reintroducing native vegetation will succeed. It is clear that graded subsoils are not easily restored without cultivation and fertilization in both terrestrial and wetlands projects.

The existing marina has proven to be an important habitat in the absence of other natural shallow water protected habitats in the area. Since Marina del Rey was created largely on dry land, and the mudflats then present supported a much different fauna than the present marina, the fish species now found have been introduced from adjacent shallow coastal waters. The productivity of the Marina is undoubtedly affected by the lower circulation of its protected configuration and the environmental insults inflicted on it by the urban environment.

Whether the new marina and the wetlands will be linked depends on factors other than physical and biological considerations. The economic concerns of developing maximum utilization of the limited Playa Vista Marina space preclude devoting much space to environmentally enhanced wall structures. Linkage of the marinas with the wetlands will require some dredging of Ballona Creek and alteration of roadways that are very costly actions, which could be subsidized by

Port mitigation funds, but there are many political pressures and competing projects for those. The answer to "Can it be done...?" is "Yes"; the answer to "Will it be done...?" is open to question.

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Shipping Safety in the Coastal Oceans

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ABSTRACT

The Marine Board has devoted much of the last two years to developing a strategy for major safety reforms in the shipping industry. As we see it, the regime should focus primarily on human factors, including improvements in management and innovation in shipboard work practices; improvements in ship design, inspection, and maintenance; advances in maritime traffic management; and more effective spill response. The paper discusses the underlying problems and suggests specific measures that would improve safety and modernize the industry if implemented as part of a comprehensive program.

INTRODUCTION

Safety has been a continuing concern of the shipping industry for decades. But when the EXXON VALDEZ ran aground off the coast of Alaska in 1989, creating the largest oil spill ever in U.S. waters, it transformed the nature of the debate. That accident brought into view the full extent of the iceberg, so to speak. Suddenly, debate no longer centered on whether safety improvements were necessary, or where to start chipping away at the problem. Rather, the industry perceived the need for major reform.

At the National Research Council, the Marine Board has devoted much of the last two years to defining the specific changes needed.[1,2] Based on committee studies and staff discussions, we envision a coordinated plan taking several basic approaches to change. These reforms would modernize and revitalize the industry

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and establish a rational, consistent, and efficient regulatory framework. Our focus has been on the U.S. trade, but the international character of the shipping industry makes many, if not all, of the findings relevant worldwide. Similarly, although we have focused primarily on one type of ship — tankers — many of the findings are relevant to all ships.

Our work clearly shows that, while the safety record is improving, the industry remains mired in outmoded traditions. And as we all know, the public is demanding a reduction in the risk of accidents and oil spills. Many links in the safety chain require urgent attention; the scope of the reform will require a heroic effort, including the discarding of time-honored practices. A halfhearted approach will not restore public confidence.

As we see it, the regime should focus primarily on human factors, including improvements in management and innovation in shipboard work practices; improvements in ship design, inspection, and maintenance; advances in maritime traffic management; and more effective spill response.

What the TITANIC did for safety of life on passenger lines, the EXXON VALDEZ should do for the safety of the shipping industry and the environment. It was a warning, a signal that it is time to rebuild the industry — and with a more reliable safety net.

SAFETY HAS IMPROVED — SOMEWHAT

The accident record of recent years indicates the industry has been moving in the right direction, albeit neither far nor fast enough. It is difficult to pinpoint any specific reason, but the factors that have contributed to better safety include improved technology, refined operating procedures, and greater regulatory scrutiny.

Statistics clearly show that, over the past 20 years, there has been a marked decline in vessel accidents, vessel losses as a result of accidents, and personnel injuries. These trends are consistent across databases, and are independent of such variables as fleet size. (See Figures 1, 2, 3, and 4.)

Likewise, the impact of accidents on the environment has been diminished. Just as the rate of serious casualties to oil tankers has declined, oil spilled due to tanker accidents and operations has decreased substantially since the late 1970s, from nearly 1.5 million tons to 569,000 tons.[1]

Nevertheless, there are continuing safety concerns that have yet to be resolved. These will be discussed shortly. There is some urgency here, due not because of public pressure to reduce accident risk, but also because developments now underway within the industry will tend to counteract safety improvements to date. For instance, tanker traffic to and around the United States is increasing, due primarily to the increase in oil imports; this increases the potential for accidents. And nearly 30 percent of crew members on U.S.-flag vessels are injured each year[2] — a rate that would hardly be acceptable in say, the airline industry.

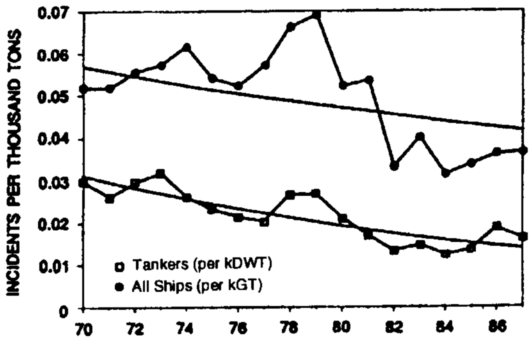

Figure 1. Reportable casualty rates of U.S.-flag ships, per thousand gross tons (upper curve), and U.S.-flag tank ships, per thousand deadweight tons (lower curve), 1970-86. For all vessels the decline has been nonlinear (power function) at a confidence level exceeding 99%. Data from U.S. Coast Guard Annual Statistical Summary.[3]

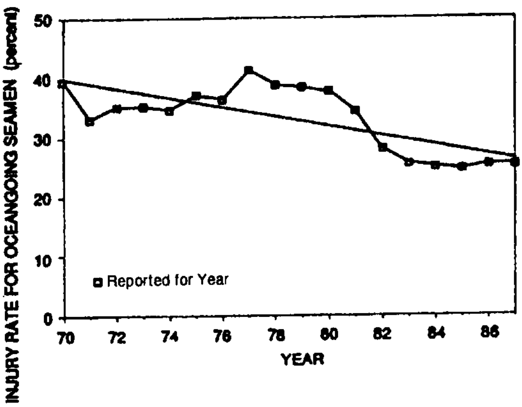

Figure 2. Annual injury rates per seagoing employee in U.S. deepwater vessels, 1970-87. The decline in the injury rate for oceangoing seamen since 1970 has been linear at a confidence level exceeding 99%. Data from Marine Index Bureau.[3]

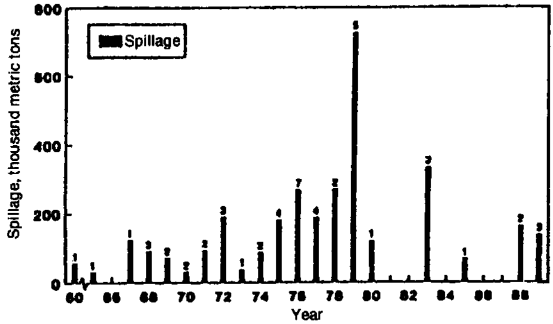

Figure 3. Tanker spillage and number of events — 50 major oil spills, 1960-89. (No major spills 1961-64. Spillage is total volume lost and burned.[1])

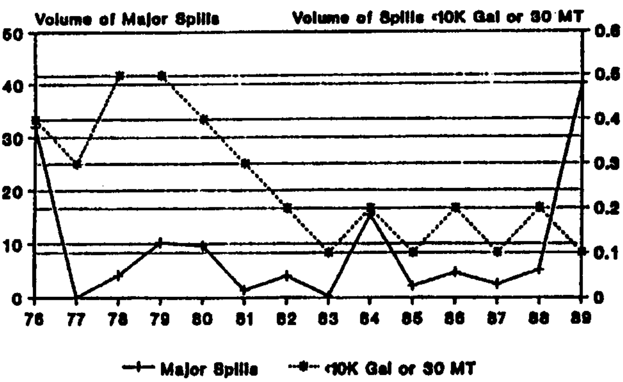

Figure 4. Tanker oil spills in U.S. waters — volume of spills. Data from U.S. Coast Guard / Temple, Barker & Sloane, Inc.[1]

PEOPLE ARE THE MAIN LINK

Ultimately, safety depends on people. Human error is the probable cause for 80 percent of vessel casualties,[3] based on the limited data available.

In the United States, the shipping environment is not optimal for fostering excellence. The maritime industry has been in decline for years; maritime-training academies and naval architecture schools have small enrollments.

Moreover, laws and regulations are outdated. Despite the steadily expanding variety of tanker types and trade routes, license standards for masters and mates still permit the operation of nearly any type or size of vessel. The Coast Guard should have more control over the qualifications of both licensed and unlicensed personnel; requirements should be stricter and more precise to reflect differences in vessel type and service.

Crewing standards are outdated as well. The structure required by U.S. law is based on obsolete technology. The division of shipboard labor into navigating and engineering teams, for example, is related to technology of the 1930's. This relic limits efficiency, with no clear safety rationale.[3] Such provisions have blocked innovation in manning.

Traditional work practices, which often are far from the norm of industrial practice, may need reform. Long work days are common in the maritime industry; fatigue appears to be a persistent precursor to casualties, although the cause-effect link is difficult to document.[4] Fatigue contributed to both the EXXON VALDEZ accident and the WORLD PRODIGY grounding in Rhode Island Sound, according to National Transportation Safety Board records.[5,6]

An important factor may be the increasing pace of work on modern ships. Turnaround time in port has been reduced, and there are too few opportunities for shore leave, rest, or relaxation. A recent study recommended that the round-the-clock duties during today's brief and intense port calls be re-examined.[7]

In the United States, many work practices are codified into law, including specific conditions and numerical requirements. This prevents regulators from keeping pace with changing conditions in the fleet; the present law is decades old and has been updated largely by piecemeal addition of specific provisions.

Even the time-honored shipboard hierarchy requires review. The absolute authority of the captain is, ironically, a source of navigation casualties. Most of the recent major polluting casualties took place with more than one person on the bridge; there is no precedent for questioning the captain's orders.

Such strict hierarchy is also less compatible with the broader individual responsibilities necessitated by smaller crews; the crew of a typical U.S. oceangoing ship is now about half the size of 30 years ago.[3] Many expect that future U.S. flag ships will be commanded by a single class of broadly qualified watch officers trained in navigational and technical skills as well as business and logistics.

Steps to improve training already are underway. Some U.S. shipping companies have undertaken programs to broaden crew members' skills, and maritime-education institutions have begun to offer courses in such topics as communication between masters and mates, and watch-keeping effectiveness.

The human element must be considered when any technological changes are introduced; ships should be considered sociotechnical systems. To date, relatively few human factors studies have been conducted in the maritime environment. Neglect of this essential component has negated many technological safety innovations of the past. The infamous TORREY CANYON spill in 1967 occurred partly because the captain, under scheduling pressure to make up time, took a shortcut through the intricate channels of the Scilly Islands.

There is no substitute for vigilant attention to safety, not only by ships' crews, but also throughout the industry. Over a period of time prior to the EXXON VALDEZ grounding, safety practices in the area had lapsed — with the tacit approval of all concerned. For instance, tankers had consistently violated traffic rules requiring vessels to slow for ice or wait for winds to abate rather than leave the normal channels.[8] Moreover, the requirement for piloting of tankers was reduced; pilots originally guided ships 70 miles from Valdez to open waters, but this distance was reduced to 12 miles.

INSPECTIONS FAIL THE TEST

When the former cruise ship SCANDINAVIAN STAR was set afire by an arsonist last year, faulty equipment was blamed for compounding the blaze. As the Miami Herald noted in a recent editorial, the ship had been inspected twice not long before — by the U.S. Coast Guard and on behalf of the Bahamas, where the ship was registered. Moreover, Lloyd's Register of Shipping had made monthly inspections through the previous month. Somehow, inspectors missed the problems. The alarm system was hard to hear in the area where many passengers died, there was no sprinkler system (none was required) and some lifeboats were corroded.

This tragic situation is illustrative of a pervasive problem: Government inspections are manpower-limited. Inspection resources have been reduced, and the agency has faced competing demands on personnel, notably for drug interdiction.[9] Between 1981 and 1989, 890 jobs related to vessel and port safety were cut from rosters. Inspections were less frequent, less thorough, and conducted by less qualified personnel. Authority to inspect foreign ships in U.S. waters was rarely exercised.[2]

Hull structural examinations of foreign-flag tankers, according to a 1989 Coast Guard study, "are at best minimal."[10] Despite the acknowledged limitations of government inspections, there are indications that shipowners have relied on them increasingly to uncover safety problems, as industry engineering staffs were cut drastically in the shipping depression of the 1980s.[10]

Tanker inspection especially is a daunting task. In a 250,000 deadweight-ton carrier, for example, inspectors must cover 74 acres of cargo tank sections and 36 miles of longitudinal stiffeners.[11] Such an inspection might require 1,000 to 2,000 person-hours. By comparison, the Coast Guard spent an average of 7.6 "experienced" person-hours on each hull inspection over a recent two-year period.[1]

Obviously, owners or their contract inspectors should conduct thorough inspections. But it is up to regulators to ensure that this is done, and the U.S. system clearly is not effective enough. To make more effective use of present staff, the Coast Guard could establish a system of annual inspections that would consist, at the primary level, of auditing management compliance with safety requirements. These requirements would be devised to cover all important areas, through, for example, mandatory recording of all routine safety tests and regular reporting to the Coast Guard of internal safety reviews. Then, based on assessment of management performance and safety records, the Coast Guard could target the time-consuming, hands-on inspections of ships to selected cases that warranted concern.

This system would provide for consistent overall oversight, while at the same time permitting extra scrutiny in cases where safety may have lapsed. A Marine Board committee has recommended this concept for inspections of offshore oil and gas development platforms.[12]

A particular concern in improving the effectiveness of ship safety inspection is the need to extend the safe operation and service of today's ships, which will comprise most of the fleet for years to come. Owners are retaining older ships in service longer, due to rising construction costs (and the U.S.-flag fleet is the oldest of the major fleets). Older vessels are more likely to incur corrosion or metal fatigue. Older vessels also have more accidents, especially fires, explosions and structural/machinery damage.[13]

Moreover, many ships have built-in design flaws. In the last 15 years, shipbuilders frequently have used high-tensile steel to achieve lighter (and cheaper) designs; but design and construction often were not well suited to the new materials, and some ships have high rates of structural failure.[14] A recent study of tankers carrying crude oil out of Valdez, Alaska found a startling frequency of major structural failures, due to poor design and construction and severe sea conditions.[15]

Another factor in planning future ship inspection programs is the new requirement for double hulls on new vessels trading in U.S. waters. This requirement, part of the Oil Pollution Act of 1990 (OPA 90), will be phased in over 25 years. The added structure and void space inherent in double hulls will increase maintenance requirements and the risk of fires and explosions.

Clearly, the Coast Guard needs to place more emphasis on inspections, and this means more resources. OPA 90 gives the agency greater authority to prevent spills, and existing statutes give the agency authority to tighten inspection of both U.S.-flag and foreign-flag ships in U.S. waters. Congress should provide the funds and legislative support to implement these reforms promptly.

NEW DIRECTIONS IN TRAFFIC MANAGEMENT

Imagine airliners in the crowded skies over New York or Tokyo, trying to avoid collisions or land without the aid of a permanent, automated air-traffic control system. Ships, on the other hand, depend entirely on the attentiveness and skills of their crew members. In our increasingly crowded shipping lanes, this tradition clearly tempts fate.

Traffic in and around the United States is already heavy. Of the more than a third of the 1.7 billion tons of crude oil and products transported annually by sea worldwide, more than a third passes through U.S. waters.[1] The Department of Energy projects a 50 percent increase in import volume by the end of the century; the increase in shipments from foreign ports may be compounded by more lightering traffic in the Gulf of Mexico.

Needless to say, the need to manage this traffic properly is growing, and the present system is minimal at best. U.S. vessel traffic monitoring systems, for example, cover only a handful of ports and waterways and are mostly advisory in nature. The level Coast Guard budgets of the 1980s were unable to support the technology required to keep up with the increasing activity in U.S. ports. Fortunately, OPA 90 authorizes a study to determine which ports and channels need new, expanded, or improved vessel traffic systems, and calls for recommendations by next summer for implementing the results.

The maritime industry clings to tradition. But as new technologies are introduced and traffic becomes more crowded and complex, ship navigation and piloting must change. The Marine Board now is reviewing the evolution of navigation and piloting, focusing on technological advances and their implications, the changing roles of the crew, pilots and safety personnel, and the related changes in training, licensing, and performance.

FASTER AND BETTER SPILL CLEANUP

Oil slicks spread with time. Thus, the longer it takes to mount a cleanup effort, the more difficult the task and the less promising the chances of success. This fact determines both the nature of effective response operations and the most promising directions for research. It also means that, in some cases, cleanup may not be worth the effort.

Clearly, better spill response is needed. Indeed, less than 4 percent of oil spilled, on average, is recovered. Accidents and oil spills will occur despite any improvements in crew standards, working conditions, inspections, or traffic control.

OPA 90 authorizes $27 million for a federal, interagency program of research and development on oil pollution. Spill surveillance is critical, and research in this area may provide significant return with only moderate funding. When the EXXON VALDEZ spill was still spreading, the distance from Valdez to one end of the slick was nearly 400 miles. Visual surveillance can't track such vast areas or determine the thickness of a slick. The possibilities for advances in surveillance capabilities are numerous. A new system should be developed employing synthetic-aperture radar and state-of-the-art ultraviolet/infrared scanners. Sensors are needed to distinguish oiled from unoiled shorelines. We should study the use of satellite data for surveillance.

We also need technologies to allow quick response to minimize spills. Quick deployment of response equipment, in particular, should be a high priority, including dispersant application, fire boom deployment, and other containment and recovery operations. We also need shipboard countermeasures, the primary option during the first six hours after a spill. However, research on quick response is high risk, in that it might require major funding without quick results.

Treatment of contaminated shorelines is also a significant concern. More research is needed on the ecological consequences of different cleanup approaches. The complex interactions among different geological conditions, oil types, and cleanup techniques is not well understood; research might lead to a decision logic that would cover a number of different options, including the option of no cleanup. The public generally demands that all oil be removed, of course, but this is not feasible.

Finally, for response technologies such as burning of oil spills and the use of chemical agents and bioremediation, field tests using experimental spills should be conducted to develop operational data and guidelines. To date, field testing has been severely neglected; only one U.S. government approval for such tests has been requested since 1979. One request is currently under consideration.

We also need to conduct long-term ecological studies of selected habitats exposed to oil. Even after 20 years of laboratory studies, sensitivities and recovery times are difficult to assess or predict.

Finally, we need to develop criteria by which to judge when a contaminated area has been sufficiently restored. A regime of toxicological, chemical, and ecological studies should be established to assess the limitations of techniques for cleanup, recovery, and restoration of different habitats.

A WORD ABOUT DATA

A persistent difficulty encountered by the Marine Board in its work on maritime safety has been inadequate information. The problem falls into two categories: gaps in engineering knowledge and incomplete, inconsistent accident records.

Too little is known about the structural behavior of ships in accidents — exactly how the hull ruptures under particular conditions. There is no way to design a crashworthy tanker, for instance, without knowing much more about the precise damage incurred in a wide range of scenarios. Building such a database would entail extensive structural review following a large number of accidents. Databases also must include such details as the speed at impact and the shape of a grounding obstacle.

This brings forth a second point: Because accident records are not maintained in a complete and consistent manner, many important questions cannot be answered definitively. There is no way to confirm a link, for example, between the dramatic reduction in crew size in recent years and the improved safety record. Tanker accident databases are often ambiguous as to whether the "cause" refers to the original casualty or to a secondary event leading to loss of cargo.[1] Moreover, different databases often must be cross-checked by hand in order to obtain a basic overall description of even one accident.[1]

A worldwide effort is needed to standardize, gather, and evaluate safety data in order to identify trends and provide the technical basis for constructive management of maritime safety.

THE INDUSTRY OF THE FUTURE

By taking the approaches outlined here, the shipping industry can shed the manacles of tradition and be transformed into a smooth-running operation that is efficient, innovative, attendant to detail, responsive to change, and above all, safe.

We envision a well-rested crew that is not hampered by outdated work practices, ever vigilant of good safety practices. We envision ships that are structurally sound, designed to withstand accidents, and inspected effectively on a consistent basis. We envision manageable patterns of maritime traffic, properly monitored. And, because tanker accidents inevitably will occur, we envision efficient and effective oil spill cleanup.

To bring this vision to reality, we first need to bring management up to date. Managers need the knowledge, tools, and environment that will enable them to meet modern expectations for safety established by other industries in the transportation sector, and to satisfy public demand for fewer needless shipping accidents and environmental insults.

Second, we need to modernize laws. An important step has been taken with OPA 90, which includes, in addition to the provisions for double hulls, vessel traffic systems, and spill research, and assigns liability and strengthens accountability for oil spills and cleanup costs. But we need to go even further, adjusting, for example, outdated laws pertaining to shipboard work practices.

Third, we need in-depth research to better understand causes and effects of shipping accidents, human factors issues in the maritime industry, and effective oil spill cleanup. Finally, the results of these studies must be put to practical use.

Achieving such a dramatic transformation won't be easy. But there is no better time or reason than the present tumult over safety — which is, after all, a matter of life and death.

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The Future of Northern Sea Route Operations – A Western View of Problems and Opportunities

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ABSTRACT

During the past six decades the Soviet Union has invested heavily in the overall development of the Northern Sea Route. The huge fleet of polar ships and the extensive infrastructure of port facilities, communications and navigation support systems in the coastal zone of the Soviet Arctic have been particularly costly. There is little doubt Soviet Arctic shipping is highly expensive relative to other sectors of the Soviet Merchant Marine — a situation that will be quite difficult to mitigate in the near future. Several critical problems, constraints and opportunities will be explored. This is primarily a Western view of a number of problems facing the managers of the USSR's Northern Sea Route under the current restructuring of the Soviet economic system. How will the use of the Northern Sea Route by other nations be planned and undertaken? How long can the navigation season be extended to support future commerce? Can the entire Route and system be made effectively self-financing? These and other issues are discussed in the context of this unique polar marine transportation system.

INTRODUCTION

Modern marine operations along the Northern Sea Route (NSR) of the Soviet Union represent a remarkable achievement as well as a large capital investment by the Ministry of Merchant Marine. The adaptation of marine technology and international technology transfer have both played critical roles in the development

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of the Soviet polar fleet that is the most significant factor making possible the extraordinary expansion of NSR operations. Since the early 1950's the increased level of support for this USSR enterprise has spawned a broad range of technical as well as operational accomplishments. Perhaps most important is that the Soviet Union has gradually gained effective marine access along much of its remote arctic coastline. Convoys of freighters have been led during various navigation seasons to all the major ports in the Soviet maritime Arctic and to each of the major Siberian rivers. It is these rivers which link the sea route to the vast heartland of the USSR. Due to this unique geography and a strong desire to develop Siberia's vast resources, the USSR has built a formidable arctic marine transportation system. Now this complex and expensive system is being challenged to function more effectively and become more economically viable. This is a difficult task due to the significant expense of operating a large fleet of state-of-the-art polar ships. One hope is that the Northern Sea Route can become a viable international trade route, particularly between Europe and the Far East, and generate much-needed hard currency for the Soviet Union.

RECENT EVENTS IN THE SOVIET MARITIME ARCTIC

Table 1 includes a number of highlights for 1987-90 involving Soviet arctic ships and significant operations. Not listed is the nearly year-round ice navigation season maintained to the port of Dudinka on the Yenisey River. Since 1978, this operation has involved the escort of freighter convoys in winter ice along a route through the eastern Barents Sea, across the Kara Sea, and into the shallow reaches of the Yenisey River. A virtual armada of icebreaking cargo carriers and technically-advanced polar icebreakers accomplish this task.

Former Soviet President Mikhail Gorbachev mentioned in an October 1987 speech (in Murmansk) the possibility of opening the NSR as an international trade route. In keeping with this unprecedented proposal, 1990 was the second year Murmansk Shipping Company chartered icebreaking freighters to Western firms to carry cargo across the NSR. During the 1989 summer navigation season, SA-15 NORIL'SK class icebreaking carriers made several transits of the NSR from Hamburg to Osaka, Japan.[1] They were the first Western shippers to charter Soviet polar ships for commercial voyages across the top of the USSR. From 13 July to 23 October 1990, SA-15 ships and MIKHAIL STREKALOVSKIY class vessels made six such voyages, carrying Western general and bulk cargoes between European and Far Eastern ports.[2] Estimates indicate that voyages between Europe and Japan would take 25 days across the entire NSR, approximately 10 days faster than voyages on a southern route through the Suez Canal.[3]

Table 1

Selected Soviet Arctic Ship Highlights 1987-90

- Nuclear polar icebreaker SIBIR reaches North Pole (25 May 1987).
- New class of SA-10 icebreaking freighter introduced with VITUS BERING (1987).
- Nuclear icebreaking barge carrier SEVMORPUT operational (1987-88).
- Shallow-draft, nuclear polar icebreakers TAYMYR and VAYGACH commissioned (1989, 1990).
- Nuclear polar icebreaker LENIN (world's first nuclear surface ship) sails on final polar yoyage (December 1989).
- Keel laid for URAL, 6th ARKTIKA class nuclear ship (1989).
- SA-15 TIKSI, under charter to foreign shippers, carries cargo from Hamburg to Osaka (August-September 1989).
- Nuclear polar icebreaker SOVETSKIY SOYUZ commissioned (1990).
- Nuclear polar icebreaker ROSSIYA reaches North Pole with Western passengers aboard (8 August 1990).

Figure 1. Soviet nuclear icebreaker SIBIR shown near the North Pole during its May 1987 expedition (from I. Frolov)

ENVIRONMENT AND THE ICE NAVIGATION SEASON

Navigation along the NSR depends mainly on the seasonal meteorological conditions and the distribution of sea ice. The ice conditions on the broad continental shelves of the region are a complex mixture of fast ice, first-year ice and multi-year ice from the polar pack. Figure 2 illustrates nine major ice massifs (or regional "clusters" of ice) found along the USSR's northern coast. For many decades Soviet ice forecasters have observed these large ice fields in the same regions each summer. The overall movement and ice concentration of each ice massif significantly influence summer ship traffic patterns along the NSR. The Taymyrskiy, Ayonskiy and Vrangelevskiy massifs, all shown on Figure 2, are the most important obstacles to marine traffic along the NSR. Each contains high concentrations of multi-year ice and frequently, heavily hummocked ice is present; the extent and duration of these conditions will substantially impact on the length of the navigation season.

A number of pioneering voyages have demonstrated the potential for extension of the navigation season on the NSR. In the early 1970s several experimental winter voyages were conducted where icebreakers led convoys of cargo ships across the Barents and Kara seas. These successes led to the year-round route between Murmansk and Dudinka. The feasibility of navigating the entire length of the NSR early in the season has been successfully tested on two occasions. During May and June 1971, the polar icebreakers LENIN and VLADIVOSTOK forged a high-latitude passage across the NSR. However, no freighters were escorted. In a celebrated operation, SIBIR and the ice-strengthened cargo ship KAPITAN MYSHEVSKIY navigated the NSR north of the Soviet island groups in May and June 1978, early for the navigation season.[4]

Although each of the experimental voyages yielded significant knowledge about winter navigation, as of 1991, neither convoys nor routine polar icebreaker transits are undertaken during the winter (January to June) east of Severnaya Zemlya. On occasion, early voyages into the Chukchi Sea have been conducted by polar icebreakers to resupply remote sites, but the ships normally do not sail west of

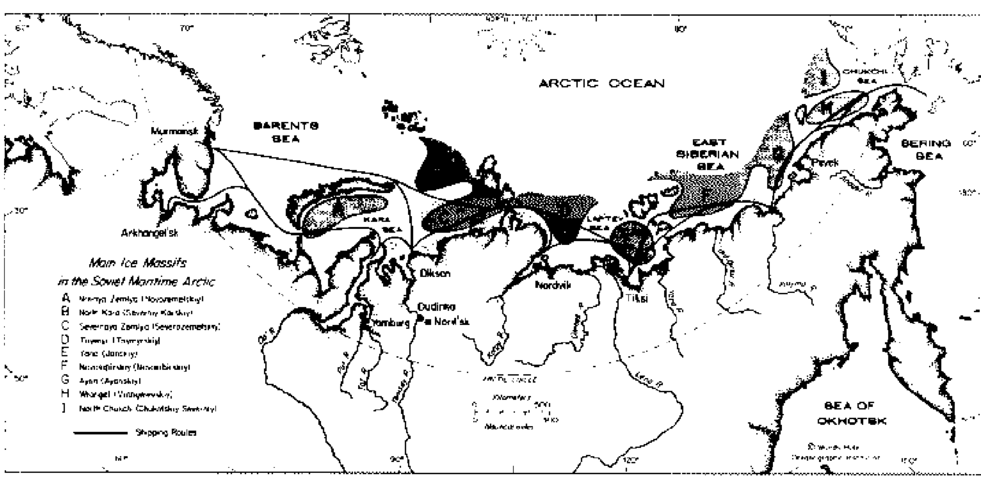

Figure 2. Shipping routes and major ice massifs or clusters along the Northern Sea Route. Most key ports and Siberian rivers are also indicated. Nearly year-round navigation is currently maintained between Murmansk and Dudinka on the Yenisey River. The significant impediments to extending the navigation season for international trade lie in the Laptev and East Siberian seas.

Wrangel Island. Clearly any limitations to navigation are due to the extreme ice conditions that exist in the Laptev and East Siberian seas during October to May.

Using the full capability of the nuclear icebreaker fleet and icebreaking cargo ships, it may be possible today to extand the navigation season in the Laptev Sea to 6-7 months. Employing the same capability in the East Siberian Sea, the potential navigation season (for reliable and cost effective marine transportation) is currently only 5-6 months in length. Thus, as an international trade route, the NSR will only be available for half the year at least until the end of the century.

COMMERCIALIZATION AND ORGANIZATIONAL IMPLICATIONS

In recent years new administrative efforts related to environmental protection in the Soviet arctic and subarctic have emerged. A 1984 decree released by the Presidium of the Supreme Soviet, entitled "Improving the Protection of Nature in the Regions of the Far North and in the Sea Areas Adjacent to the Northern Coastline of the USSR" set forth a legal framework for regulating shipping, air transport, construction, mining, oil exploration and other development activities in the arctic. Included in the decree are provisions for imposing administrative and criminal penalties on vilators. In response to the decree, oil pollution control measures for ships and ports have been introduced by the Administration of the Northern Sea Route. However, further commercialization of the NSR would require a regulatory regime that should include strict navigation seasons and "zones" for the safe navigation of specific ship classes.

Even minor increases in arctic shipping activity would pose environmental threats related to oil pollution, waste dumping and cargo loss. The extreme cold and remoteness of the Soviet maritime Arctic surely require new environmental strategies. The development of these strategies coupled with expanded traffic along the NSR will also place new pressures on the sensitive organizational relationships that have evolved between Soviet institutions engaged in arctic regional planning and management.

Despite some notable successes in arctic marine transportation, interorganizational friction and conflict between the NSR shipping companies and the various agencies charged with planning the Soviet Arctic' s future, have created barriers to the effective development of the overall system. Figure 3 illustrates the complex network of organizations and relationships among the key Soviet institutions responsible for arctic shipping. The introduction of additional administrative functions and regulatory regimes related to environmental protection will increase the level of uncertainty and add considerable complexity to those organizations with arctic management responsibilities. Another significant complication may be the future economic and regulatory roles of Russia, since the entire Soviet Arctic (and therefore all operations along the NSR) lies within this largest of the fifteen Soviet republics. Future foreign vessel transits of the NSR would clearly be of major concern to regional and local organizations as well.

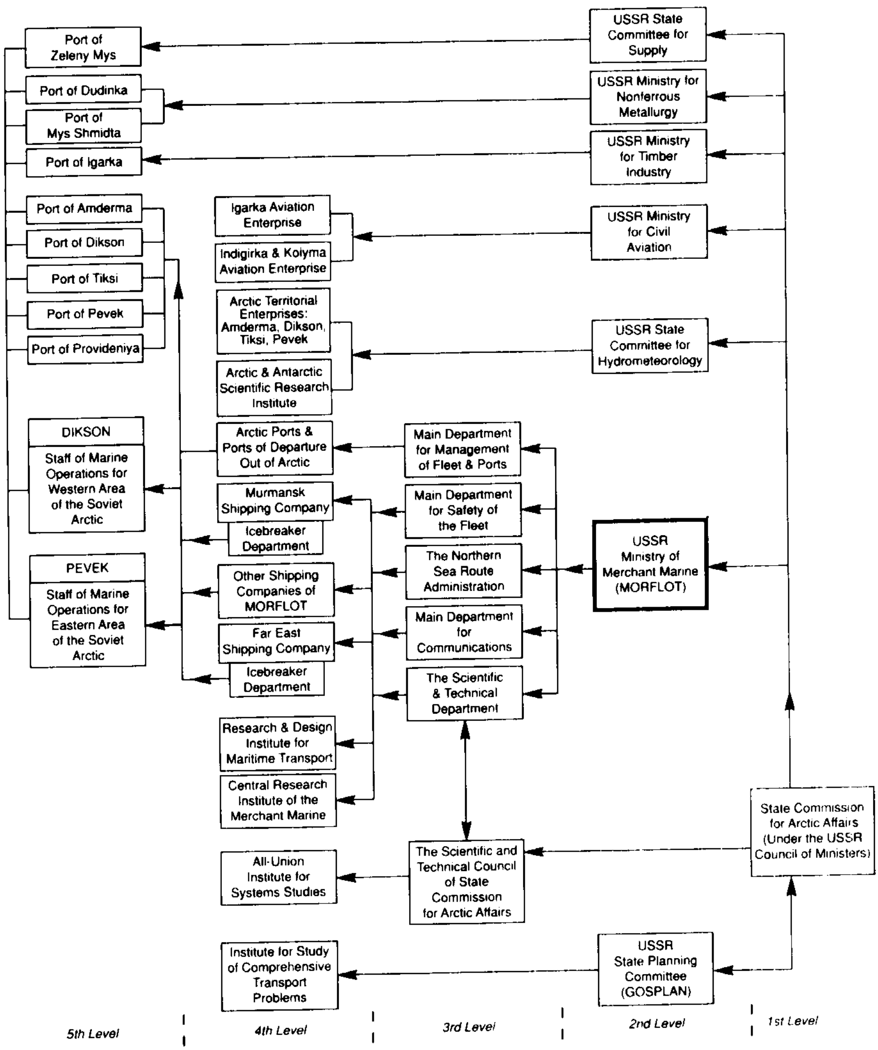

Figure 3. Organizational diagram for Soviet Arctic shipping management and operations. The State Commission for Arctic Affairs was established in 1988 to coordinate (from a "national" perspective) all activities in the Soviet North.

Further use of the NSR by foreign shippers (by chartering Soviet icebreaking vessels or sailing Western ships along the NSR) will be one way to underwrite the NSR's operation and generate hard currency. However, many of the commercial and operational mechanisms to support a full-scale international shipping route have yet to be set in place. Questions related to cargo liability, insurance, tariff levels and pilotage (all of which are in the commercial realm) must be resolved. Issues related to weather and ice data reporting, use of forecasts, route planning, polar icebreaker assistance, and port capabilities will require operational solutions.

PROSPECTS FOR THE FUTURE

The recent restructuring of the Soviet economic system provides the most difficult challenge to the continued and perhaps expanded operation of the NSR. For how long and with how much funding will the system continue to be subsidized by the Ministry of Merchant Marine? Since 1 January 1988 most organizations of the USSR, including all shipping companies, were to be established on a "cost-accounting" basis. Developing an equitable, cost-accounting or cost-sharing program so that arctic shipping might become self-financing will be a monumental task. Such expensive marine operations (with huge attendant overhead costs) will be very difficult to transform in the short-term. In addition, competition for a share of smaller allocations of national funds to the Ministry of Merchant Marine will make the situation particularly difficult for arctic shipping companies. This comes at a time when larger budgets may be necessary for fleet additions (primarily more modern and capable icebreaking cargo carriers) and equipment improvements.

There are several options for use of the NSR by foreign shipping companies. Western firms might continue to charter Soviet polar ships for single, through-passages or for longer, possibly seasonal periods. The voyages during 1989 and 1990 were charters of this type. Another alternative would be for Western merchant ships to transit the NSR (in convoy or individually) under escort by Soviet icebreakers. Currently, however, there are few foreign merchantmen with adequate ice-strengthening that are capable of safely navigating in convoy along the NSR. A third option might be to transfer various cargoes to Soviet icebreaking ships waiting at both ends of the NSR — possibly in Alaskan ports and in Dikson or Murmansk. This might be a workable system provide the cost of this specialized Soviet service is attractive and the navigation season can be extended, at least partially in the Laptev and East Siberian seas. The NORIL'SK class ships (SA-15 icebreaking cargo carriers) would be the most likely choice for such a joint venture with Western shippers. Both the nuclear and conventionally-powered barge carriers might also be employed, thereby enhancing their effectiveness.

Owing to the present economic state of the USSR, large capital expenditures for the Soviet polar fleet would appear to be seriously constrained. However, a number of icebreakers and icebreaking cargo ship classes (built during the 1950s and 1960s) will be reaching the end of their respective service lives during the 1990s. Any replacement strategies may be forced to consider a somewhat smaller, yet more capable arctic fleet for the future. One indication of this is a trend toward increasing icebreaking capability through the continued addition of nuclear icbreakers of the ARKTIKA class. The shallow-draft nuclear icebreakers TAYMYR and VAYGACH are also very significant and highly capable additions that will operate several decades into the next century. Moreover, new technological developments will likely be applied to replacement icebreaking cargo carriers. The experience of operating the SA-15 ships (built in Finland during 1982-87) should be influential in the determination of the appropriate size, power and type of future Soviet polar cargo ships. Foreign designs will no doubt be influenced by these same vessels. In many respects the buildup of more capable Soviet polar icebreakers may force a comparable investment in more capable cargo ships that may be escorted (if only along the most difficult stretches of the NSR) or sail independently a majority of the time. Larger and better carriers may, in turn, require a substantial investment in the improvement of arctic port facilities. Thus, formidable challenges exist with regard to the appropriate distribution of capital costs for both a ship replacement program and for improvement of the large NSR infrastructure. Western capital provided under joint venture arrangements may be a viable solution.

Future prospects for maintaining the year-round navigation season to Dudinka appear promising. Major icebreaker suuport in this region has been available for more than a decade. Icebreaking on the Ob and Yenisey rivers will, in fact, be improved with the operation of the shallow-draft TAYMYR and VAYGACH. However, extensive use of large icebreakers on this western segment of the NSR, particularly during February through May, is obviously costly and contributes to the overall economic performance of the system. Improvement in the economic situation may come from a strategy of having improved icebreaking cargo ships sail without icebreaker assistance (independently) for as long into a given navigation season as feasible. This might be the future case for Western oil and gas carriers sailing the NSR from fields in the Barents Sea to ports in the Far East.

High-latitude voyages (north of the island groups and in the central Arctic Ocean) have been shown to be technically feasible by nuclear polar icebreakers. Yet a future convoy on such a route would face difficult operational challenges. Any such transArctic route will probably not become economically viable until well into the next century. Although the navigation season in the Laptev and East Siberian seas may be extended to at least six months, the current economic development of the region may not yet require such an advance. Only if the NSR's season is lengthened for both national and international reasons, will such investment be justified. Also, sea transportation will face increasing competition from the Siberian river fleet, particularly to ports along the Lena River. Thus, any expansion of arctic marine traffic will be linked to the overall planning far the entire transportation system in Siberia.

The Soviet Union has developed an extraordinary marine transportation system for its arctic coastline. This system is in many respects of national economic importance since the NSR links much of the remote and vast Siberian lands. Even during the extremely difficult economic situation of today's USSR, ships continue to be added to the arctic fleet. It is clear that the NSR remains an important link to the major Siberian rivers. Making the NSR a cost-effective and efficient international trade route will be a challenging undertaking; Western capital would improve the chances of success. However, the economics of such a venture must be determined and a host of regulations must be devised before the NSR can become a viable commercial operation.

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Development of A Floating Module — HMS

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ABSTRACT

A unique floating module has been developed. A basic module has a hexagonal shape, thus it is called an HMS (Hexagonal Marine Structure). The HMS is made of six trapezoidal pre-stressed concrete pontoons, which are assembled to make a hexagonal shaped float. The HMS can be used independently or several units assembled together. The advantage of the HMS is its easy construction and flexibility in application. It can be assembled into as many units as required and assembly work can be performed while the units are afloat. The HMS is useful as a mooring pontoon, floating stage, heliport, work station and other purposes.

BASIC DESIGN OF THE HMS

The basic shape of the HMS is shown in Figure 1. Six hollow trapezoidal pre-stressed concrete floats are joined together to form a hexagonal shape. In order to assemble these trapezoidal floats, joining faces of each float are bonded together by waterproof glue or mortar. At the same time, every corner of the joints is fixed by high tension bolts. In some cases, diagonal bracings are placed to give additional compressive stress to each floating unit in order to increase the rigidity of the structure.

The unit float is constructed either in dry-dock or on the shore and then assembled together in the water. This prefabrication method enables construction

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of the HMS at any location even where no large-sized machines or yards are available.

The cross-section indicates that the HMS has the shape of a catamaran and is quite stable to prevent overturning. This characteristic is the same for all faces.

FIRST PROTOTYPE

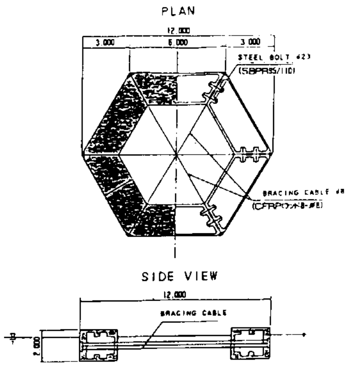


Figure 1. Standard HMS

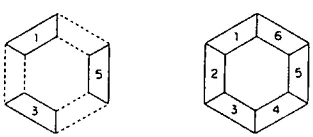


Figure 2. Match casting of HMS

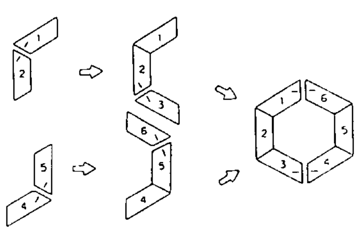


Figure 3. Joining process

The first prototype was built at Yokohama in 1987. It has a 6 meter unit length, 2.0 meter deck width and 2 meter depth. It is 92 tons dry weight. Each flotation unit was built using reinforced concrete.

Construction of the flotation unit was done onshore. In order to secure precise fittings of the joining faces of the floats when they are assembled, a match casting method was adopted. Figure 2 illustrates match casting of the HMS.

Assembly work was carried out while the units were afloat on the water. Each flotation unit had keys to fit against other units so that they set in the right position without difficulty. This operation could be accomplished even with some wave action.

After six units were joined into one HMS shape, each face was fixed with high tension steel bolts. At the same time, the joining faces were bonded to each other with waterproof glue.

Finally, six sets of Carbon Fiber Reinforced Plastic (CFRP) rods were installed diagonally as bracings which gave compressive stress to the joined faces. Thus, compressive stress would be distributed to each flotation unit and would prevent hair cracks in the concrete. One set of diagonal bracings consisted of 3 rods.

The CFRP used for the bracing is made of long carbon filaments 8 microns in diameter and combined with epoxy resin to form a 8mm diameter solid rod. The rod has parallel filament structure and has a very strong tensile strength of 180 kgf/mm^2. An 8mm rod has a strength of 8,800kgf. The specific gravity is 1.6.

A 33tf tension for each rod or total tension of 99tf for one set of the braces was introduced. This tension gives 8kgf/cm² compressive stress to the concrete.

The bracings could be made with steel rods instead of the CFRP. Steel rods, however, become subject to corrosion, particularly when the HMS is used in sea water. The CFRP is immune from corrosion and yet has similar tensile strength as a steel rod.

The CFRP used for the first prototype HMS was a solid bar. Some of the carbon filaments were exposed directly to the surface. This resulted in an awkward situation when the rod was in contact with steel members. The steel in contact with carbon had tendency to corrode faster than under normal conditions. At a later date, improved CFRP rod with surface insulation was developed and this corrosion problem was eliminated.

DURABILITY TEST AT LAKE INAWASHIRO

Immediately after the success of the first prototype test at Yokohama, a similar size HMS was built at the east coast of Lake Inawashiro, Fukushima prefecture, for a durability test.

In this lake there was no drydock to accommodate construction of the HMS. Therefore, the flotation units were built on shore. When they were completed each unit was carried from the construction yard to the waterfront by a trailer and launched into the water.

One flotation unit of the HMS at Inawashiro is 6.0 meters long, 2.3 meters wide and 2.0 meters high. The total dry weight (6 units) is 92 tons. The units were joined together on the water and CFRP cables were installed diagonally to give pre-stressing to the concrete.

The HMS, after completion, was anchored in the lake. Various gauges and sensors were installed on the HMS to measure its stress and dynamic behaviors in the water.

SEA PAVILION AT YOKOHAMA EXPOSITION

A 2000 ton HMS was built and installed at the EXPO site of Yokohama for the Sea Pavilion Stage. It was 20 meters in unit length, with a 6 meter deck width and 5 meter depth. Diameter of the assembled HMS is 40 meters.

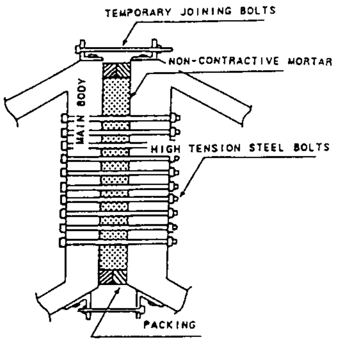


Figure 4. Joint with non-contractive mortar and bolts

The HMS was to serve for (1) mooring berths for exhibition boats, (2) dolphin show stage and (3) aqua dome (fish dome).

This HMS was much larger than the first prototype. Because of its size, the match casting method was no longer practical. A special joint was made, and between the joining surfaces non-contractive mortar was injected. The joint is shown in Figure 4. Assembly work of the units had to be done outside of the dock, where the previous HMS was assembled, and required more precaution against waves and wakes of other vessels.

Water quality in the inner pool of the HMS was another problem, because the water quality around the site was not always good for keeping dolphin and fishes. Therefore, a canvas bottom was attached at the bottom of the inner space to separate outside seawater. The water in the HMS pool was filtered at the nearby seabed and pumped into the pool. The water quality in the pool was kept clean and visibility was satisfactory.

In the case of Yokohama Pavilion, no diagonal cable was placed to give pre-stressing to the concrete. Instead, the flotation units were built by adopting pre-stressed concrete axis-direction members in each block. The reasons for not using the diagonal bracing cable were that the water was calm around the moored site and no severe stress was expected. Also, the inner water space had to be used for the dolphin pond. The diagonal cables would obstruct free water space for swimming dolphins.

The normal live load for the HMS at Yokohama is 0.5person/m^2 or 300 persons on the deck. Such a load can be concentrated on one side of the deck floor. When the live load is distributed evenly, the total number of people that can be accommodated is 600.

A MOORING PONTOON AT LAKE TOWADA

New HMS mooring pontoons for trout fishing boats and pleasure boats are going to be constructed at Lake Towada. They are the first HMS to be in permanent use. The proposed HMS has a 20 meter unit length, 14 meter breadth and 40 meter diameter. The total dry weight is approximately 750 tons. The flotation unit is built by partially pre-stressed concrete and joined together by high tension steel bolts at the corners.

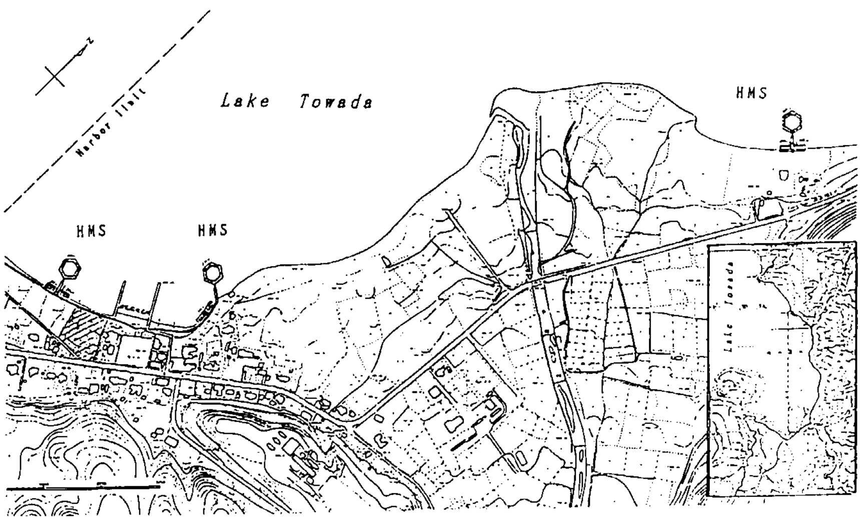


Figure 5. Proposed location of HMS sites at Lake Towada

The main reasons for selecting the HMS at this site are as follows.

1. The proposed site has considerable water level fluctuation, because the water of the lake is used for hydroelectric power reservoir. Therefore, a floating type is preferable.

2. The lake is designated as a national park where no shipbuilding yard is permitted in the area. Consequently, the HMS is a convenient structure which does not require a special yard for construction.

3. The designation of a national park restricts land reclamation in the lake.

4. The design wave height is relatively low and construction of the float and their mooring system becomes simple.

5. The HMS system always provides leeside berth regardless of the wave and wind direction. The site is not protected by any breakwater and construction of a breakwater is not possible.

As shown in Figure 5, a total of three HMS will be built in the lake in three years. The first one will be completed by the end of 1991.

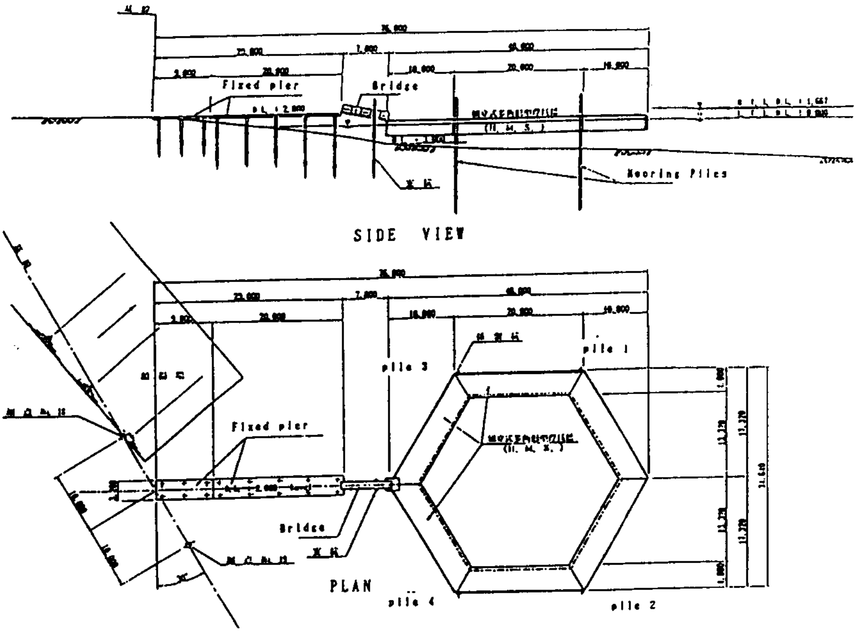


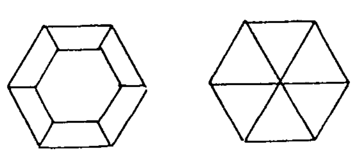
Figure 6. General plan of the HMS at Lake Towada with pile mooring

APPLICATION OF THE HMS AS A FLOATING MODULE AND VARIATIONS IN COMBINATIONS

Basic Variation

An HMS is hexagonal in plan. The width of the flotation unit, however, can be variable. When the width of the float is increased to the maximum, the trapezoid shape becomes virtually a triangle and there is no open space left at the center of the HMS.

Those HMS with wider width in each flotation unit have the advantage of having a wider space on the deck as well as durability against waves and other outside forces. On the other hand, a wider width means heavier weight as a whole.



(a)standard (b)triangle float

The length of a flotation unit determines the size of the HMS. If the length is great the total size or the diameter of the HMS becomes large. The optimum size of the unit float is determined by its usage and the availability of building facilities.

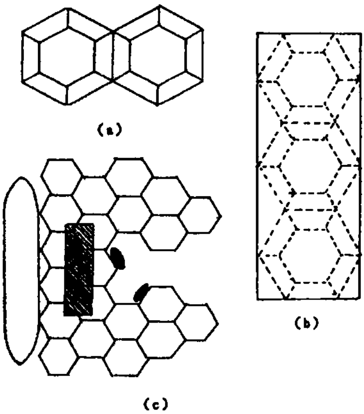


Figure 7. Multiple HMS variation

When a larger space is required with the HMS system, multiple linkage of the HMS will be a solution. Several HMS's can be joined freely with each other so that a group or groups of HMS's can be used as a floating pier, floating breakwater, floating stage and other purposes.

Figure 7 indicates various plans of multiple HMS linkage. Plan (a) indicates a twin type. Plan (b) is a triple or multiple series type with covered deck. It can be used for a mooring berth for larger vessels and/or various working platforms on the water. Plan (c) is an example of a multiple HMS complex.

Single HMS

A single HMS is the basic form of the HMS. As already used at Yokohama and planned at Towada, the main purpose is for a mooring berth for pleasure boats. Advantages of the HMS for a mooring berth are (a) various directions of the berths always provide leeside berths, which may eliminate difficulty for berthing with wind or wave of any direction, (b) the difference of berthing direction for each berth enables the vessel's berthing without interference with neighboring berths.

The inner water space of the HMS can be used for various purposes. At Yokohama, the space was used for the dolphin show pool. It may also be used for a fish preserve pool or swimming pool.

If the inner water space is covered with a deck, the HMS will become a wide platform. This is not only suitable as a boat mooring pontoon, but also for various other purposes including a heliport, marine work station, etc.

When a superstructure is built or placed on an HMS, naturally the center of gravity of the whole structure will be raised. The HMS, however, normally has a sufficient margin of stability and an additional superstructure can be safely loaded within its safety limit.

Figure 8 is an example of a single HMS rigged for a heliport. The flight deck will be raised to a certain height above the original HMS deck so that the flight deck has a sufficient safety margin from water splash. The space below the flight deck can be used for a lounge, office, store etc.

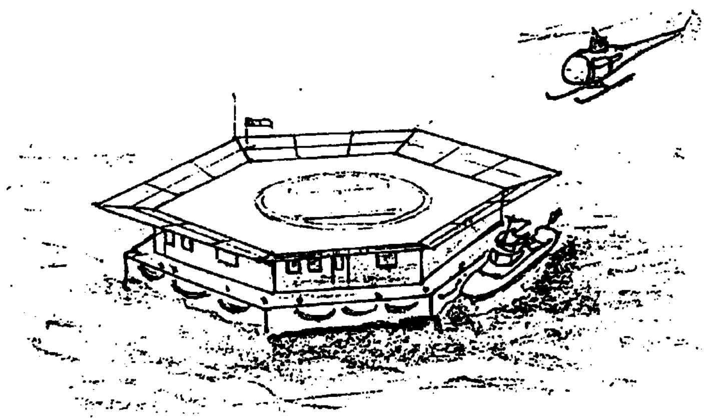


Figure 8. Single HMS heliport

Multiple HMS

The multiple HMS is suitable when and where a wider or longer space is required. A single HMS has a limitation in its size governed by the building facility for the unit float length. If a longer or wider space is required, the HMS's can easily be joined together while they are afloat.

When joining HMS's, any length of berth can be provided within a short period of time, and its extension or reduction in length is very easy. Furthermore, if multiple HMS's are joined together, numerous alternatives for layout become possible. At the same time, modification of the layout is relatively easy when compared to other type of structures.

The multiple HMS can also be used for a temporary or permanent floating breakwater.

Various diversions of HMS flotation units

When an HMS become unusable by any reason, all or part of the flotation unit can be re-used by rearranging the joining. By fixing alternately as indicated in Figure 9 (a), a straight long float can be made. This straight float can be used for a mooring pontoon or a floating breakwater. If the joints are arranged differently, various combinations of shapes can be made.

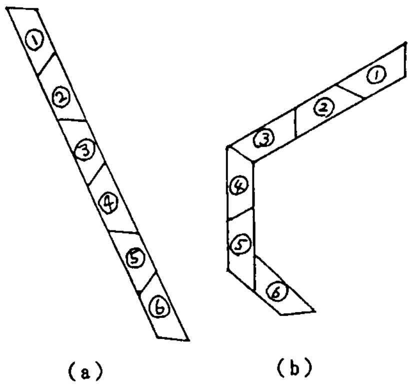


Figure 9. Diversion of unit float

CONCLUSIONS

The HMS was created as a floating module for multiple usage. It can be used either singularly or in multiple combinations. The important features of the HMS are:

1. A sizable floating pontoon can be provided without a large scale building dock.
2. Sufficient stability and rigidity enable a HMS to be used for various purposes at sea.
3. By joining a number of HMS's, any shape or any size of floating space can be created. And joining work can be done while they are afloat.
4. Because of the module concept, construction of many HMS's or a large HMS complex can be built with relatively low cost and in a short period of time.
5. For joining the HMS's in the water, high tension steel bolt fixtures are normally used. If special corrosion prevention is required, CFRP rods or cables may be used instead of high tension steel bolts and pre-stressed high tension steel bars.
6. The shape of the HMS has various berthing directions, which always provides leeside berths and berthing operations without interference with other berths.

Several areas are still left for further study and development. Some of them have already been studied, such as dynamic stability against waves, analysis of stress and strain of the HMS, and anchoring systems, etc. Stress and strain analysis for a large number of HMS complexes against long period waves, the effect of the HMS as a breakwater, the optimum size of the flotation unit etc., are items for further study and development.

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Deployable Waterfront Facilities

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ABSTRACT

Deployable Waterfront Facilities consist of large floating modules connected to form a variety of waterfront structures. The structures can be used to replace conventional piers, wharves and waterfront facilities and have the additional attribute that the structure formed can be disassembled into component modules which are transportable and thus the structure itself is relocatable. The modules can be specifically built to the requirements of the port, transported from the building site and connected and anchored to form the port complex. The Deployable Waterfront Facilities can replace or augment existing stateside port facilities. Additionally, the modules can be prepositioned for rapid overseas deployment, installed as replacements or augmentation for overseas bases or stored in CONUS as contingency assets. Mission specific modules can be constructed, as required.

Deployable Waterfront Facilities can provide a port facility tailored for a specific mission and adaptable to a specific site. Because of the modular nature of the facilities, it is possible to pick a group of individual modules suited to a particular mission or objective. This capability allows the utmost in flexibility, while requiring transportation of only the material needed to the site. Transportation is carried out using ocean tows for module deliveries which are not time critical and using heavy lift semisubmersible ships, capable of maintaining 16 knots, for contingency, disaster relief or other time critical installations.

Construction of the modules can be carried out in shipyards. This allows construction to proceed without tying up vital port operation areas. Once built, the modules can be installed at a specific port site in a matter of weeks. The system allows for a staged buildup of a port by addition of modules and also allows for

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reduction in capability as a site is reduced in importance. Deployable Waterfront Facilities are a recoverable asset. As requirements change, assets can be withdrawn from an area and reused to provide a base at a new location.

INTRODUCTION

Deployable Waterfront Facilities consist of large floating modules connected to form a variety of waterfront structures, Figure 1. The structures formed can be used to replace conventional piers, wharves and waterfront facilities and have the additional attribute that the structure formed can be disassembled into component modules which are transportable and thus the structure itself is relocatable. This would provide the Navy with the capability to augment existing ports both in the U.S. and overseas. In addition, the flexibility afforded would permit movement of piers as priorities and commitments changed.

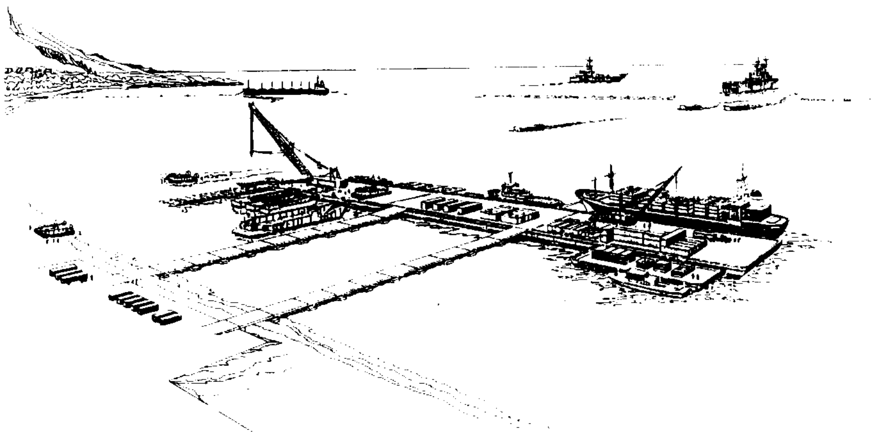

Figure 1. Deployable Waterfront Facilities

BACKGROUND

Each time U.S. forces have become engaged, there has been a priority scramble to establish the required forward-based logistics support structure. When waterfront facilities are required, they have in general been hastily assembled and moved into support locations, usually at the expense of early operational effectiveness of the engaged forces, or at worst remain an operational deficiency . The requirement for waterfront facilities occurs at a time when there is a high demand for the military construction units and little capability within these units to construct large waterfront facilities. Prior planning for the basic structures that will provide the logistic support required could significantly shorten the time and effort required to construct them.

During World War II, the distance factor in the vast Pacific theater necessitated creating numerous temporary waterfront facilities. These included repair ships, floating drydocks, barracks ships, machine-shop barges, and massive amounts of lighterage and supply storage space that were temporarily required by the naval forces in the island-hopping campaign. In the Atlantic theater, the prefabricated "Mulberry port" for Normandy was the single most spectacular feat in advanced waterfront facility deployment. The facility was designed to handle 12,000 tons of cargo and 2500 vehicles per day. The first ship was offloaded at the port at D+11. This facility showed what a success prior planning for a temporary port could be. It should be noted that even this well designed and constructed temporary port could not escape the ravages of severe weather conditions.

When the Korean conflict began, it was fortunate that there were U.S. bases in Japan close enough to provide logistics support. Even then it was necessary to rapidly assemble and move mobile facilities into forward positions around Korea to support naval operations. Inchon, Pusan, Wonsan, and Hungnam are specific examples of hastily assembled advanced logistics support sites that were crucial to the conduct of the naval operations in support of that campaign.

With United States involvement in Vietnam, forward based logistics support sites again became a priority issue in force effectiveness. Ships were delayed excessively because there were inadequate facilities in the Republic of Vietnam for offloading. Engaged forces initially operated at reduced levels of effectiveness because of supply limitations. Floating pier sections were hastily assembled and moved to Cam Ranh Bay to begin the development of a major port. The port at Da Nang required the installation of major temporary facilities for the support of naval operations in the Gulf of Tonkin and the I Corps area. Due to the length of time that U.S. forces remained in Vietnam, many of these pier facilities were converted to a semipermanent or permanent condition. When U.S. forces left, a large nonrecoverable investment remained behind with no residual value to the United States.

The British deployed a floating pier facility to the Falkland Islands in March 1984 to support after action operations. Six offshore oil field, ballastable support barges were outfitted in England and transported 8,000 miles via semi-submersible heavy-lift ships. This facility provided 900 feet of ship berthing, 18,000 ft^{608} of quayside work area, 1,270,000 ft^3 of covered storage, and a roll-on/roll-off (RO/RO) facility. The link to shore was provided by 600 feet of ballasted causeway. The onsite installation took about 75 days. The Falkland Islands Port and Storage System was installed at a prepared site in a protected inner harbor whose major environmental loads were high winds. The system was engineered specifically for the topography and sea bottom conditions at the Falkland Islands, and was capable of off-loading self-sustaining RO/RO ships.

Base rights in Middle East nations are in a state of change. In general, forces operating in that area have had to depend on host nation support. Rapid completion of the base at Diego Garcia and the creation of the Near-Term Pre-Positioned Force (NTPF) and the MPS projects were steps taken to offset logistics deficiencies. However, without greater flexibility in the establishment of forward support bases and reliable ship-to-shore interface facilities, critical operational limitations are imposed. Sealift support ships require port facilities for efficient offload in forward areas. Even if the specific ships are configured for self-offload (self-sustaining), pier facilities and/or extensive lighterage are required to move the cargo and vehicles ashore.

STATUS/DISCUSSION

Currently our Naval bases overseas are fixed facilities installed using conventional construction techniques. These bases are site specific and non-recoverable. A recoverable system will allow increased operational flexibility. The possibility of relocating the base throws a new variable into the equation, Figure 2. In addition, complete port systems can be stored at strategic deployment sites ready to respond to contingencies or provide disaster relief, Figure 3. The modular nature of the system allows tailoring to the specific operational needs. Because the modules are preconstructed and installation is rapid, improvements to existing or damaged ports will not tie up critical waterfront areas with longterm construction projects.

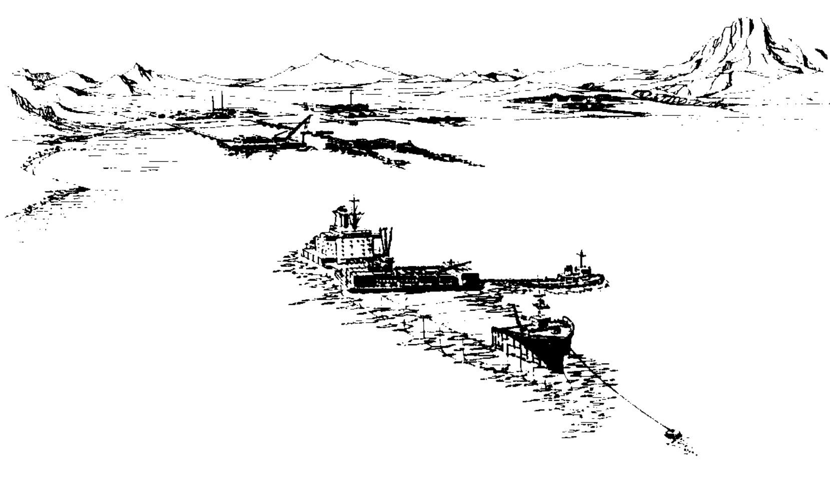

Figure 2. Relocatable Waterfront Facilities deploying from Heavy Lift Semisubmersible Ship

CONCEPT DEFINITION

An analysis of the current situation, and the historical background to the defined problem, reveal that there are three specific areas of concern:

1. A need for a capability to rapidly assemble and transport mobile logistics facilities that are tailored for the support of amphibious operations.
2. A need for a capability to rapidly assemble and transport mobile logistics support facilities to forward and remote areas of the world for the support of forward deployed Battle Groups and Fleet Forces.
3. A need for greater flexibility in home-porting fleet units so that a vulnerable concentration of forces can be avoided.

A concept is required that effectively embraces all of these needs and provides an operationally and cost-effective approach. Such a concept is embodied in the Deployable Waterfront Facilities. This concept proposes to employ large floating modules as the foundation for the assembly, transport, installation, and operation of basic waterfront facilities. The modules selected, and the specific facilities installed thereon, are determined by the nature of the support required. The technology to support the development of a family of facilities on large floating modules structures has been proven to be feasible for facilities in protected areas.

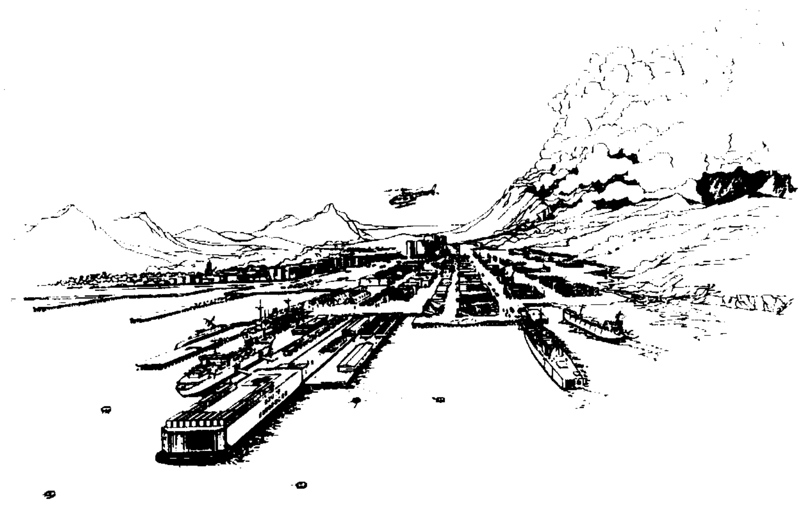

Figure 3. Deployable Waterfront Facility used for disaster relief

Range of Capabilities Required

The major feature of the Deployable Waterfront Facilities which set them apart from current expeditionary cargo handling facilities is the capability of berthing ships directly. This will allow operations in up to sea state 4. To support the offloading of these ships, the pierhead must support offloading equipment for 40 foot containers. The offloading equipment must be capable of moving 20 containers per hour. The water depth at the pierhead will range from 50 feet to 150 feet. The complete facility must be designed for quick installation and relocation. The time to install will be on the order of a few weeks with a similar time frame to prepare for relocation. The waterfront facility may either use land based storage in conjunction with a causeway linked to the shore, or provide its own storage facilities and be totally sea-based. The design of the facilities will minimize manpower requirements and provide for automated cargo handling wherever possible. The facilities will be designed and built to withstand a range of environmental loads and permit installation in various seafloor types to allow flexibility in site selection.

Current Technology Investigations

Current Navy research efforts are aimed at developing the capability to install and operate the Deployable Waterfront Facilities on exposed coastlines, and at offshore and marginal sites. The development of a capability to install a deployable waterfront facility on an exposed coastline will require the development of better open sea connectors, high capacity propellant embedment anchors, transportable breakwaters, and improved design techniques and capability. Improvements are also being pursued in container handling capability, module connectivity and prediction of transport loads.

Technologies currently under investigation include:

Module Connectors — Connecting a number of 5,000 ton, 100 by 300 foot barges for operations in the open ocean is a unique operation. Information on existing connector systems, ranging from simple tow configurations to complex tug/barge connectors is being researched and new connector concepts are being developed. Over twenty module connector concepts have been identified or developed. The restoring force versus module separation properties of each connector are substantially different. This makes the selection of the best concepts for further development difficult. A computer simulation model that will allow quick analysis of the motion and forces between modules given the connector properties is under development.

Transportability — Heavy lift semisubmersible ships are in limited supply. All of the eighteen ships identified have sufficient lift and deck space to accommodate Deployable Waterfront Facilities modules. Studies of ship stability, wave slamming loads and tiedowns for modules mounted athwartships are underway. A computer program being developed will allow calculation of loads on ship/barge seafastenings. We do not currently have the capability to determine wave forces on the overhanging portion of barges being transported by heavy lift semi-submersible ships, Figure 4. With the capability to determine the forces we will be able to determine efficient seafastening design.

Breakwaters — Recent developments in expedient breakwater technology are being investigated for application to the Deployable Waterfront Facilities. These new developments will be entered into a data base for a Breakwater Expert System. The expert system prototype is operational with a limited set of rules.

Linear Induction Motor Technology — The linear induction motor (LIM) container mover system provides automated cargo movement between the pierhead and shore. An automatic control device sequences power to the correct linear induction motor and the magnetic flux generated moves the container along the LIM track. At the beach end, the containers roll onto siding tracks where they are removed by container handlers. This automated LIM container transfer system will significantly increase cargo handling capacity, reduce manning requirements and conserve trucking assets.

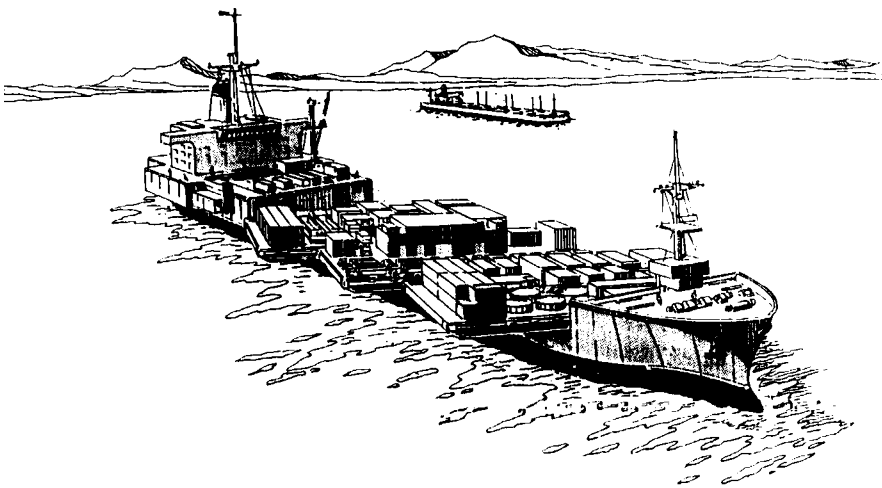

Figure 4. Transport of DWF modules by Heavy Lift Semisubmersible Ship

Pile Technology — Use of a vibratory pile driver will eliminate the need for a pile extractor. This will reduce the equipment required for relocating the Deployable Waterfront Facilities. Comparison of the pile bearing capacity when driven with a vibratory driver to the bearing capacity when driven with an impact driver is needed to use this method of driving as a replacement for the existing impact drivers.

Universal Footing — A footing incorporating a spudcan, with a rock spike, and a water jet array will provide a rapid pile installation technique for sediment seafloors. Compared to conventional pile driving, the universal footing achieves the desired penetration very rapidly in sediments. Research has shown the universal footing to be effective in both sand and mud. The current research is to determine the effectiveness of the universal footing spike in rock materials.

Rock Anchor — A propellant embedment anchor (PEA) provides a single anchoring technique for sediment or rock seafloors. Current efforts are to develop the technology of the rock projectile PEA. Successful tests have been run using smaller rock projectiles and a series of tests to determine long term holding capacity is currently underway. Additional development work is planned with large projectiles (8000 lb) having ultimate capacities of 300,000 to 500,000 pounds in sediment or rock. These will be used to moor the Deployable Waterfront Facilities modules. A crane or winch lowers the PEA launcher to the seafloor where the propellant charge is ignited. The gases generated in the barrel by the burning propellant force the projectile into the seafloor at speeds of 300 to 500 feet per minute. Seafloor penetration depths are dependent on seafloor material and projectile type.

CONCLUSIONS

Development of certain key technologies will permit the deployment and construction of the Deployable Waterfront Facility. The Deployable Waterfront Facility can sustain cargo operations in conditions up to sea state four. Other Deployable Waterfront Facility improvements are a deep water cargo offloading berth, and an automated cargo handling and transport system. The Deployable Waterfront Facilities will significantly change the way the Navy conducts overseas operations. This system will provide ships berths and cargo handling facilities with the ability to relocate and the capability to be tailored to fit specific missions. These advantages add up to increased operational flexibility.

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A Design Manual for Floating Structures in Japan

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ABSTRACT

Recently, development in the coastal zone has actively promoted the creation of comfortable areas where the port and harbour are placed in the heart of an area. These projects are promoted by local government, and the Ministry of Transport cooperates by promoting the projects and paying special attention to the planning and the safety of facilities.

Among those projects are some facilities which consist of floating structures. These floating structures should be moored even in storms such as typhoons, which create large motions and induce large mooring forces. As for operation, the motion of floating structures must be minimized to secure the safety and comfort of customers.

This paper describes the present state of floating structures and briefly introduces the recently compiled *Design Manual for Floating Structures in Japan*.

INTRODUCTION

As Japan is surrounded by the sea, the coastal zone has been highly utilized. In particular, ports are important as nodes of land and sea traffic where commercial and industrial activity occur. As the function required of ports is changing with time, the features of ports are also changing gradually.

During Japan's great economic growth since 1960, secondary industry, especially heavy and chemical industry, was intensively promoted. Subsequently, the amount of cargo handled in ports and harbours increased substantially, so that

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eventually ports came to serve primarily as industrial sites and cargo distribution facilities. During this same period of economic growth, however, an increase in leisure time and a growing awareness of environmental issues led people to expect port areas to be clean, quiet areas for recreation and communing with nature.

The Bureau for Ports and Harbours, Ministry of Transport, Japan established the *Vision of Ports and Harbours of Japan in the 21st Century* in 1985 as the long term policy for promoting port facilities, with an awareness of the change in public opinion and long-term expectations. The text of the *Vision of Ports and Harbours of Japan in the 21st Century*, advocates improvement of port facilities to create a composite ports and harbours area where facilities for physical distribution of cargo, industries, and citizen life are all located organically. In particular, the public interest in the waterfront has increased so much that the primary thrust of port facilities improvement has been toward creating a pleasant recreational environment for the public.

As mentioned, the development of waterfront has proceeded in various places inside and outside of ports and harbours areas. Among the facilities constructed are floating structures used for museums, exhibition halls, marine restaurants and convention halls. Floating facilities have been constructed since about 1960, and at the beginning, facilities were constructed which utilized deluxe passenger and/or freight ships such as *Hikawa Maru*, moored in the basin in front of the Yamashita Park in the Port of Yokohama. On the other hand, several new floating facilities have been constructed, such as *Marine Pavilion* exhibited for the Yokohama Exotic Show and *Floating Island* placed in the Sakaigahama Marine Park. The structural type of floating structures varies and the sizes are increasing. And some facilities are located at rather deep sea and/or at sites with soft soil conditions.

The increasing numbers and sizes of floating structures required that some standards be applied to their design, in large part to ensure public safety. The Bureau for Ports and Harbours therefore established the *Design Manual for Floating Structures* to meet the demand. This paper provides a basic overview of the manual.

PRESENT STATE OF FLOATING FACILITIES

Major floating facilities constructed up to this point are listed in Table 1. Descriptions such as "12,000GT" in the column "Properties" means that facilities utilize used deluxe passenger and /or freight ships.

Table 1

Floating Structures Constructed up to the Present

No	Name	Opened	Purpose	Location	Properties	Capacity (people)
1	Hikawa Maru	1961	Restaurant	Yokohama	12,000GT,163m	331
2	Kanawa	1962	Restaurant	Hiroshima	27m	
3	Hiroshima	1965	Restaurant	Hiroshima	21m	
4	Show Boat	1969	Theater	Ishikawa	54m	459
5	Scandinavia Maru	1970	Hotel	Numazu	5, 105GT, 127m	113
6	Hoo Maru	1973	Restaurant	Matsushima	16m	24
7	Hoo Maru	1973	Restaurant	Matsushima	16m	56
8	Brazil Maru	1974	Restaurant	Toba	10, 216GT, 156m	2,000
9	Aquapolis	1975	Exhibition	Okinawa	104X100X32m	
10	Ryugu	1976	Restaurant	Nojiri Lake	25m	150
11	Shioji	1978	Restaurant	Toba	180GT, 39m	102
12	Soya	1979	Museum	Tokyo	2,734GT, 83m	
13	Aquarium ship	1982	Aquarium Ship	Amakusa	50m	1,500
14	Manho	1983	Restaurant	Saga	22m	250
15	Sun Urashima	1984	Restaurant	Toba	350CT, 26m	160
16	(Restaurant)	1985	Restaurant	Tamano	28mX20m	100
17	(Floating Pier)	1985	Restaurant	Toya Lake	28m	120
18	Fuji	1985	Museum	Nagoya	5, 250GT, 1OOm	521
19	Prince Willem	1985	Exhibition	Nagasaki	1,460GT, 73m	300
20	Oriana	1987	Restaurant	Beppu	41, 920GT, 245m	6,650
22	(Floating Pier)	1987	Mooring	Inawashiro	12X10.4X2m	
23	Marine Pavilion	1989	Exhibition	Yokohama	40X34.6X5m	
24	Floating Island	1989	Exhibition	Onomichi	130X40X5m	

Note: Blank spaces under "Capacity" mean unknown.

The first floating facility is *Hikawa Maru*, completed in 1961, moored in the basin in front of Yamashita Park in the Port of Yokohama. Floating facilities are mostly used for restaurants, exhibition halls and museums. *Oriana* in the Port of Beppu and *Hakkoda Maru* in the Port of Aomori are similar types of facilities to *Hikawa Maru* and are moored at the specified point by fenders, chains and/or mooring ropes.

On the other hand, there are several floating facilities which are newly constructed, such as *Aquapolis* exhibited at the Okinawa Exposition of Ocean, *Floating Island* in Sakaigahama Marine Park and *Marine Pavilion*. These facilities are constructed using hexagonal marine structures (H.M.S). These floating structures are called "moored ships" according to the Ship Safety Law, and the safety of the floating facilities is examined according to both the Ship Safety Law and the Port and Harbour Law. Figures 1 through 8 show instances of floating structures and their mooring facilities constructed up to this moment.

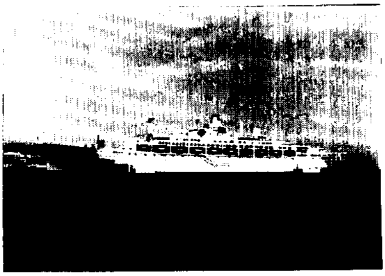

Figure 1. Oriana

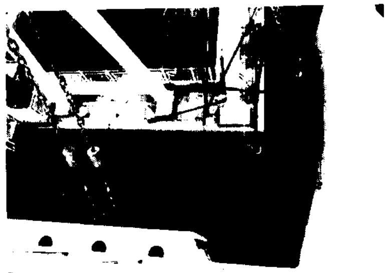

Figure 2. Fender of Oriana

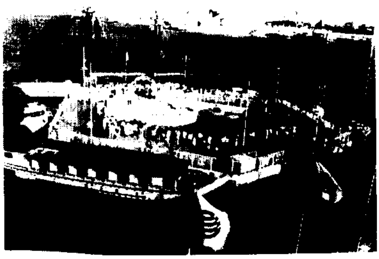

Figure 3. Marine Pavilion

Figure 4. Show at Marine Pavilion

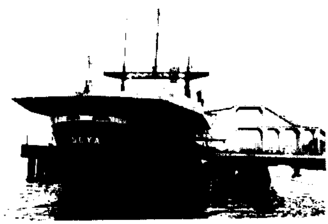

Figure 5. Soya

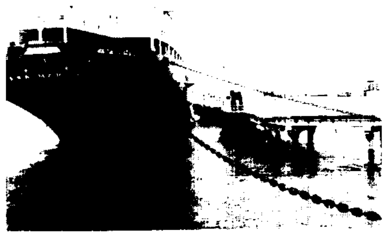

Figure 6. Hikawamaru

Figure 7. Floating Island

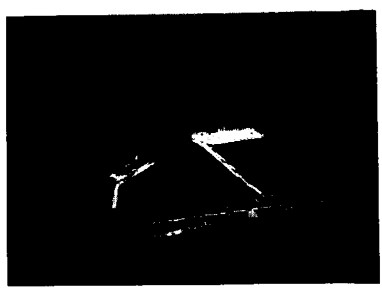

Figure 8. Floating Island

Floating structures have been constructed mostly in bays or lakes or at sites where the basins are well sheltered from ocean waves by a number of islands and/or peninsulas; however, some facilities are constructed offshore where wave and wind conditions are rather severe. In those cases, the design of mooring facilities becomes most important. Table 2 lists design conditions of recently constructed major floating facilities.

For these floating facilities, much attention shall be paid to the examination of the safety of the mooring facilities, especially against typhoons. The procedures of the examination are specified as follows.

1) Estimation of the design wind speed for the required return period related to the life time of the floating structure.
2) Estimation of the design wave condition for the required return period.
3) Calculation of wind force and wave force acting on the structure and also radiation forces induced by motions of floating structures.
4) Determination of the load deflection characteristics of mooring facilities.
5) Calculation of motions of the floating structure and mooring forces.
6) Design of the mooring facilities in conformity with the safety requirement.
7) Detail design of floating structures.

Devices and materials used for mooring facilities are mooring dolphins, rubber fenders, chains, anchors, sinkers, mooring ropes (wire ropes, synthetic ropes such as nylon ropes). As rubber fenders and mooring ropes have non-linear load deflection characteristics, the properties of mooring facilities should be determined taking account of deflection due to both stationary forces and variable forces of wind and waves acting on floating facilities simultaneously.

SECURITY OF FLOATING FACILITIES

General

Safety of floating structures and their mooring facilities shall be examined based on the Port and Harbour Law and the Ship Safety Law. As for the "Technical Standards for Port and Harbour Facilities with Commentary" (hereafter the Technical Standard) based on the Port and Harbour Law, prescription is made on the proper use of water area and the security of floating type port facilities and their mooring facilities, and mooring facilities of restaurant ships and other moored ships. And as for the Ship Safety Law, prescription is made on the security of human life and the stability of moored ships.

Table 2

Design Conditions of Major Floating Facilities

	Oriana	Fuji	Soya	Hakkoda Maru	Floating Is
Design Wind Speed	33. 9m/s(50 year return, corrected to sea wind)	Ordinary: 16m/s Special : 60m/s	Maximum Inst Wind Speed 50m/s	30m/s or 23m/s S,W,N,E ESE,SSE 100 year return	28m/s 100 year return
	T⅓H⅓	T⅓ H⅓	T⅓ H⅓	T⅓H⅓	T⅓ H⅓
Design Wave	NNE 6.0s,2.1m N E 7. Oz, 2. 5m ENE 7,0s, 3.3m E 7.0s, 3.3m ESE 6.2z, 2.9m S E 4.75, 1.9m	Ordinary:1.4s,0.5m Special 3. Oz, 0. 6m	6.0s,3.0m	N 7.35, 0.8m NNE 7. 35, 0. 8m N E 7.35, 0.8m 100 year return N 6.7s, 1.0m NNE 6.75, 1.0m NE 6.75, 0.9m 10 year return	4.0s, 1.5m
Seismic Coeff.	K_h=0.1	K_h=0.2	K_h=0.2		
Tidal Level	HHWL 3.40m HWL 2.10m LWL 0.00m	HHWL 5.35m HWL, 2.60m LWL 0.00m	LWL 0. OOm	HHWL 1.50m HWL 0.8Om LWL 0.00m	HHWL 4. 4.95m HWL 4.12m LWL 0.00m
Type of Mooring Facility	Dolphins Rubber Fenders	Dolphins Rubber Fenders Chains Nylon Ropes	Dolphins Rubber Fenders	Rubber Fendres Nylon Ropes	Chains Sinkers
Properties of Mooring Facility	Buckling Type 1,250H~3, 000H	Buckling Type 300HX4, 500L Nylon ϕ58 Nylon ϕ65	Buckling Type 300HX2,500L	Hyperbolic Type 2,500HX4,500L Nylon ϕ75~80	Chain Grade#2ϕ76 Grade#2ϕ78

Application of Port and Harbour Law

Construction, improvement or maintenance of port and harbour facilities shall be in conformity with the Technical Standard, according to Para. 2 of Art. 56 of the Port and Harbour Law, whether the facility is located inside or outside the port area.

1) Waterways and basins; channels, anchorages, basins.
2) Protective facilities for harbour; breakwaters, sea walls revetment, groins.
3) Mooring facilities.
4) Facilities for passengers boarding (fixed and movable type).
5) Facilities for port traffic (limited to port facilities).
6) Cargo sorting facilities.
7) Storage facilities.
8) Facilities for ship services.

The following prescription is made on the Technical Standard.

1) Proper arrangement of facilities related to other utilization of water area.
2) Security of port facilities concerned to structural safety.
3) Security of user of port facilities.
4) Smooth use of port facilities.

Conformity with the Technical Standard is examined by the head of the port authority or the governor of the local government. As for fishery ports, the Fishery Port Law shall be applied excluding those ports applying the Port and Harbour Law.

1) Port Area: Permission from the head of the port authority according to Art. 37 of the Port and Harbour Law (including the neighbouring area to the port area).
2) Waterfront Area: Notice to the head of the port authority on construction and improvement of waterways and basins and also according to Para. 2 of Art. 38 of the Port and Harbour Law.
3) Official Noticed Area: Permission from the governor of the local government according to Art. 56 of the Port and Harbour Law.
4) Basin excluding above mentioned: Notice to the governor of the local government according to Para. 3 of Art. 56 of the Port and Harbour Law (including rivers, lakes and marshes and private basin).

The Technical Standard was generally revised in 1988. In the previous version, description was provided only for small pontoons placed in the basin against rather small waves; however, in the revised version, description is provided for floating structures generally corresponding to various types of floating structures. As a detailed description is not provided even in the revised version, additional details were requested. Thus, the *Design Manual for Floating Structures* was compiled.

Ship Safety Law

Prescription is made for hull, engine, lifesaving, fire prevention equipment, migration equipment, hygiene equipment, electric equipment, mooring equipment and so on in Para. 1 of Art. 2 of the Ship Safety Law. Detailed technical standards are prescribed by the Ministry of Transport Ordinance concerning hull and equipment of ships (rules on hull of steel ships, rules on equipment of ships rules on lifesaving equipment of ships, rules on fire prevention equipment, etc.).

Moored ships shall apply the Ship Safety Law. Moored ships are those facilities listed below which are used by a number of passengers. For ships with double or layer decks, the areas to be used shall be enclosed.

In principle, rules for ordinary passenger ships shall be applied to moored ships; however, taking into consideration the peculiarity of moored ships, part of those rules are mitigated or intensified.

Purposes of moored ships are as follows:

1) Theaters, cinema theaters, entertainment halls.
2) Town halls, assembly halls.
3) Cabarets, coffeehouses, night clubs.
4) Recreation halls, dance halls.
5) Assignation houses, restaurants.
6) Eating houses.
7) Department stores, markets, shops, exhibition halls where things are on sale.
8) Hotels, inns.
9) Libraries, museums, art museums.
10) Car parks.
11) Gymnasiums, swimming pools, athletic grounds or playgrounds.
12) Offices.
13) Aquariums.
14) Observatories.

According to Art. 5 of the Ship Safety Law, moored ships shall undergo regular inspection, intermediate inspection and extraordinary inspection and certification shall be issued to those moored ships which pass the inspection.

THE DESIGN MANUAL FOR FLOATING STRUCTURES

Circumstance of the establishment

As mentioned above, construction of floating structures is intensively promoted in Japan, and those facilities often will be located in deep waters where waves and wind are more hostile. On the occasion of the revision of the Technical Standard, prescription was made for floating structures more generally, taking into consideration the present trend of construction of floating structures; however, detailed prescription was not made. Then the Bureau for Ports and Harbours entrusted the Coastal Development Research Institute to organize a committee to compile the *Design Manual for Floating Structures*. The committee consisted of Dr. Goda (professor of Yokohama National University) as the chairman, members from Nippon Kaiji Kyokai, and those organizations belonging to the Ministry of Transport, such as the Bureau for Maritime Technology and Safety, the Bureau for Ports and Harbours, the Ship Research Institute, the Port and Harbour Research Institute and the Second District Port Construction Bureau. The committee identified and addressed a number of problems, taking about a year to compile the Design Manual.

Purpose and Limit of Application

The *Design Manual for Floating Structures* specifies items which are not dealt with in the Technical Standard and was compiled for referral in design, planning and examination of floating type port facilities and mooring facilities, and mooring facilities of restaurant ships and other moored ships. The manual shall be applied for those floating facilities and their mooring facilities listed below.

1) Floating berth, car parking ships, warehouse ships, and other floating type port facilities (mooring buoys, small pontoons, floating breakwaters, and floating oil storage facilities are excluded because there are no established items beyond the description in the Technical Standard).

2) Mooring facilities for restaurant ships, museum ships and other moored ships which are limited to those facilities applied to the Ship Safety Law.

The location of floating structures shall be selected properly, taking into account the conditions of occupation of the basin inside the port area, effect on ship navigation and environment in the neighbourhood, meteorological and marine conditions such as wind, waves, current and so on.

Design of Floating Facilities

Basic conception of design

Design of floating facilities shall comply with the Port and Harbour Law, and examination of the function and the safety of the floating facilities shall be made. Design of floating structures is broadly classified into design of the main body of floating structures and the mooring facilities, as aiming at the parts.

Design conditions

The following items shall be considered as design conditions of floating facilities, and examination shall be made on the function and the safety of floating facilities:

- Waves
- Sea level (tide, storm surge, tsunami)
- Current (tide current, tsunami flow)
- Wind
- Soil conditions
- Surcharge
- Earthquakes, littoral drift, drift ice

Here, the return period for design wind and waves shall be properly determined considering the importance and the lifetime of floating facilities. The return period is the average number of years for an occurrence of phenomenon in excess of the design level.

The probability of wind speed is estimated by use of data observed at the weather bureau in the neighbourhood of the location. Data shall be obtained for a long enough period, and yearly maximum mean wind speeds analysed, fitting data to the appropriate extreme function and estimating the wind speed for the required return period. As wind speed and waves vary, consideration of gustiness and irregularity of waves as well as attention to the load-deflection characteristics of the mooring facilities is recommended.

It is also recommended to avoid locations where tsunami may occur frequently; however, if there is apprehension of tsunami, the current speed of tsunami and the safety of the mooring facilities must be considered.

Stability of floating facilities

Stability of floating facilities shall be examined with consideration of reaction forces from connecting bridges, surcharge and leakage at certain blocks. As for surcharge, examination on the inclination and the free board shall be made with consideration of the eccentricity of loads.

Analysis of motions of moored floating facilities

Analysis of motion of moored floating facilities shall be made in accordance with the appropriate method, with consideration of the irregularity of loads and the non-linear load-deflection characteristics of mooring facilities. In particular, if the load deflection characteristic is non-linear and/or asymmetrical, it is recommended to do numerical simulation to estimate the motions of floating facilities. The results of the numerical simulation shall be statistically analysed to estimate the maximum expected values of the motions and mooring forces of floating facilities. There are two different types of load-deflection characteristics of rubber fenders called buckling type fenders (exhibit constant reaction force against about 20% to 40% of deflection to the height) and hyperbolic type (exhibit hyperbolic load-deflection characteristics). Buckling type fenders exhibit hysteresis on unloading. The load-deflection characteristics which shall be used for numerical simulations are determined based on the published performance diagram in a catalogue issued by a fender manufacturer with consideration of the variation of the load-deflection characteristics due to individual differences, temperature, repetition of loading, bi-axial loading, dynamic response, creep and deterioration.

Table 3 lists the standard of deviation for each item. On the analysis of motions of floating facilities, loads and the combinations listed in Table 4 shall be considered.

Table 3

Deviation of Fender Characteristics
(Deviation of Reaction Force against the Same Deflection)

Individual Difference	0. 9 – 1. 10
Deterioration	1.0 – 1.05
Dynamic Response	1.0 – 1.10
Creep	Fender reaction force caused by stationary loads shall be less than the fender reaction force against 10% of deflection
Repetition of Loading	0.8-0. 9 (ten times of repetition with the intensity equivalent to the fender reaction force against 40% of deflection
Bi-axial Loading	Loading with 10% of shear force against compression
Temperature	0.95 – 1.25 (corresponding to 50°C - 0°C)

Table 4

Combinations of Design Load for Analysing Motions of Floating Facilities

Items of Conditions	Ordinary	Storm	Special Cases Earthquake	Tsunami
Wind	O	O		
Waves	O	O		
Current	O	O		O
Tidal Level	HWL,LWL	HWL,LWL		O
Storm Surge		O		
Temperature	O	O		
Earthquake			O	

O: shall be considered

Structural intensity of floating facilities

Materials such as pre-stressed concrete, reinforced concrete, steel and a hybrid structure of steel and concrete may be used for construction of floating facilities. The materials shall be selected considering the characteristics and the costs. Examination of the structural intensity of floating facilities will involve such loads as dead weight, hydrostatic pressure, buoyancy, wave force, wind force, wheel load, earthquake load, reaction force of fenders and mooring forces with consideration of loads and the combinations listed in Table 5.

Table 5

Combinations of Design Load for Examining the Structural Intensity

Items of Conditions	Storm	Earthquake	Tsunami
Dead Weight	O	O	O
Surcharge	O	O	O
Snow, Stikked Ice	Δ	Δ	
Wheel Load	Δ	Δ	
Hydrostatic Load, Buoyancy	O	O	O
Wave Force	O		
Radiation Force	O	O	O
Curren Force	Δ	O	
Wind Force	Δ		
Earthquake Load	O		
Tsunami			O
Ice Pressure	Δ	Δ	Δ
Mooring Force	O	O	O
Collision Force	Δ		

O: shall be considered, Δ: considered occasionally

Design of the mooring facilities

The type of mooring facilities shall be selected with consideration of such items as size of floating facilities, water depth, materials and length of chains and/or mooring ropes, with or without intermediate sinkers and soil condition of the sea bed. Generally, the chain system and/or the wire system may be employed in relatively deep sea, and the intermediate buoy system and the intermediate sinker system, dolphins, piers and bollards and bitts may be employed in relatively shallow water. The combination system of wire and chain was employed in the deep sea, for instance. Anchors and sinkers are used in the chain and the wire systems. Piles, rubber fenders, and mooring ropes are used for dolphins, piers, bollards and bitts. As chains may hinder navigation and mooring of ships, piles may be used in the sheltered calm basin.

The type of mooring facilities shall be selected in conformity with following items and criteria.

1) To be safe and efficient under ordinary conditions for cargo handling and boarding and disembarkation of passengers.
2) To be safe against extraordinary conditions such as typhoons or earthquakes.
3) Water depth, construction cost, precedent.

The *Design Manual for Floating Facilities* explains how to determine the properties of the mooring systems for the chain system and the dolphin with fender system. On the other hand, for the dolphin with fender system, the safety of the dolphin against earthquake loads shall be determined by use of the seismic coefficient method, the response spectrum method and the numerical simulation method, which are explained in the *Design Manual for Floating Facilities*.

On the detail design of mooring facilities, the allowable load of mooring ropes, chains, rubber fenders, holding power and the required safety factors of anchors and sinkers, the thickness allowance against corrosion and abrasion, design load for dolphins are prescribed in the *Design Manual for Floating Facilities*.

The allowable load or stress or deflection should be related to the reliability of the analysis, probability of occurrence of the phenomena, duration of loading, frequency response and so on. In the *Design Manual for Floating Structures*, the allowable load or stress or deflection of mooring facilities and others was established according to the prototype and/or model experiment, taking into consideration the computation method. However, this subject requires further discussion.

Maintenance of floating facilities

As facilities are floating and are composites of floating bodies and mooring facilities, abrasion and corrosion of parts is a major concern; therefore, more attention shall be paid to maintenance than for ordinary port and harbour structures. Major items of maintenance are specified as follows:

1) Strength of mooring ropes; in particular, much attention shall be paid to deterioration.
2) Corrosion and abrasion of chains.
3) Change of characteristics for repetition of loading, deterioration and creep of rubber fenders.
4) Corrosion of bodies of floating facilities and cracks of concrete and so on

CONCLUSION

Construction of floating facilities is increasing in accordance with recent active development of the coastal zone. More event facilities, convention halls, marine restaurants, floating berths and floating piers for pleasure boats are going to be constructed in the future. The *Design Manual for Floating Structures* was compiled by the Coastal Development Institute for Technology after prudent discussion by the committee, consisting of Professor Goda as the chairman, members from the Nippon Kaiji Kyokai, the Bureau for Ports and Harbours, the Bureau for Marine Technology Safety, the Ship Research Institute, Port and Harbour Research Institute and the Second District Port Construction Bureau. However, several subjects should be discussed further, such as allowable load or stress or deflection of the facilities. Furthermore, studies are necessary for mooring methods for floating structures constructed in more hostile seas.

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Institutional and Management Issues

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Coastal Zone Space: Invitation to Conflicts

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INTRODUCTION

The coastal zone, the narrow strip of land and water where both meet in the ocean basins, provides society with many resources: recreation, waste space, farming and ranching, habitat and transportation. Some national economies are nearly totally dependent upon its existence. Developing nations look to it as a source of much needed revenues. Its very attractiveness is leading to conflicts among those who seek to exploit its resources, especially where their proposed activities are not mutually compatible, In this paper, I will survey the important, existing uses of the coastal zone and how they can impact upon each other and upon the quality of the environment. The importance of the resources will be considered for both the developed and developing countries.

TOURISM AND RECREATION

Tourism accounts for around 5% of the world's gross national product.[10] The contribution of the coastal zone to that of the inland parts of a country has not yet been determined, but for many island countries it may be very close to 100%, where tourism is the only contribution to the economy. Tourists are defined (to a large extent in order to gather statistics for economic and social studies) as temporary visitors spending at least 24 hours in an area for purposes of leisure (pleasures, holiday, health, study, religion, sport) or business (mission, conference or family). As the number of affluent people in the world increases, so does the number of

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tourists. The World Tourism Organization indicates that on an international basis the number of travelers rose from 69 million in 1960 to 160 million in 1970 and 404 million in 1989. These figures do not include excursionists, those who spend one day or less in a place, or cruise passengers.

For some relatively non-industrialized countries, like many of the Caribbean Islands, the annual rate of growth of tourism is substantially greater than the world average.[1] The Caribbean Islands have experienced an annual rate of growth of 7.4% since 1984, significantly greater than the world value of 5.8%. Although economic benefits can be substantial, they can also result in environmental, social and cultural sacrifices.

The involvement of tourism to the economies of the developed countries can be seen in a recent OECD survey (Table 1):[10]

Table 1

The Contribution of Tourism to the Economies of some OECD Nations

Country	Comments
USA	6.0% of Gross National Product (GNP)
Canada	4.0% of GNP
United Kingdom	4.0% of GNP
Switzerland	6.2% of Gross Domestic Product (GDP)
Turkey	3.0% of GNP
Yugoslavia	10.0% of foreign exchange earnings
Portugal	9.0% of GDP
Norway	3.3% of GDP
New Zealand	3.9% of GDP
Italy	8.0% of GDP
Germany	4.6% of GDP

Source: OECD, 1989.

The contributions to the total tourist economy from that of the coastal zone has been approached by Grenon and Batisse.[3] They estimate that in France 18% of the domestic tourism and 19% of the international tourism is involved with the Mediterranean coast. For Tunisia and Yugoslavia the comparable figures are 80% and 90%, respectively.

Some Caribbean nations, on the other hand, to a large extent support their populations with the revenues from tourism, which have been rising steadily during the past decade. The visitor expenditure as a percentage of the gross domestic product can be quite high (Table 2). The coastal zone plays a most important role as a tourist attraction.

Table 2

Visitor Expenditures in Caribbean Countries as a Percentage of Gross Domestic Product

	1980	1985	1988
Antigua & Barbuda	44	77	78
Bahamas	45	53	53
Barbados	33	28	34
Belize	4	6	21
Bermuda	59	74	85
Jamaica	9	20	16
Puerto Rico	4	4	4
St. Vincent & Grenadines	28	25	35
Trinidad & Tobago	2	2	2

Tourism revenue can compensate in part for that lost to imports.[3] It accounts for 25% in Spain, between 10 % and 20% in Cyprus, Malta, Tunisia, Greece, Israel, Morocco and Italy. For Italy, the tourist monies would equal in value one-third of the hydrocarbon imports or 80% of the food imports. It sponsors ten percent of the work force in Israel and between 3 and 6 percent in Malta, Italy, Spain, Tunisia, Yugoslavia and Greece.

Standing in the way of the extension of tourism is the improper waste husbandry practiced in many countries. Beaches are soiled with discards from domestic, industrial and agricultural sources. Tourists seek clean recreational areas and safe-to-eat seafood. For example, the beaches in the northern Adriatic are strewn with rotting algae as a result of the entry of plant nutrients from farming activities in the drainage area of the Po Valley and the consequential fertilization of coastal waters. Recreational activities have come to a standstill. The loss of tourist revenues in northern Italy and Yugoslavia is not trivial, nor is the loss of recreational facilities to the local inhabitants of these areas.

The quality of coastal zone waters can be of great concern to tourists with respect to their health. Discharges of inadequately treated domestic and industrial wastes can lead not only to the over fertilization of coastal waters, but also to the entry of pathogenic microorganisms.[2] In the former case, phosphates and nitrates can over-stimulate plant growth. In some cases red tides and plankton blooms containing toxin-containing dinoflagellates result.

Morbidities and mortalities can be brought about by exposure to coastal waters through recreational activities and through the consumption of seafood, the latter being more important. (The following discussion is taken in large part from Noble, 1990.[9]) The illness-causing agents are microorganisms which come into the waters from sewage outfalls, coastal run-off, other humans, or as toxins accompanying the organisms in plankton blooms and red tides.

The shellfish which carry toxins or pathogens encompass the bivalve molluscs which live in the intertidal zones. They are filter feeders, extracting particles from waters, often at the rates of liters per hour. Oysters, clams, scallops and mussels are the primary vectors for the removal of toxins and pathogens from the water into the human diet.

There are three types of organisms responsible for illness and death from eating seafood. First, there are the dinoflagellates, small photosynthesizing organisms, which in certain species and at certain times of the year can contain toxins giving rise to unpleasant diseases (PSP — paralytic shellfish poisoning, NSP — neurotoxic shellfish poisoning, and DSP — diarrheic shellfish poisoning). Second, pathogenic viruses that bring about human disease enter recreational areas primarily through domestic waste outfalls or with human participants. The two most important agents are the Hepatitis A virus and the Norwalk virus. The latter is by far the more significant. It is responsible for one-half of the occurrences of epidemic, nonbacterial gastroenteritis in the United States. In 1982 there were outbreaks involving 103 well-documented cases in New York State alone. Eighty percent were associated with eating raw clams and the rest with eating raw oysters. There was also a 26% incidence in the disease among people who ate cooked clams.

A third set of diseases is related to the consumption of bacteria such as those responsible for typhoid fever and cholera. The latter has recently reentered the U.S. scene. No cases were observed from 1911 to 1973, but from 1973 to 1985, 31 illnesses came about from eating raw seafood, especially oysters.

The perception of illness in coastal areas from seafood and/or exposure in the coastal environment can potentially result in the loss of revenues, especially if there has been a recent well-publicized incident in the country to be visited by tourists. Balancing revenues from tourism against sums necessary for the proper control of microorganisms and toxins can vex environmental managers.

The tourists themselves can contribute to coastal zone degradation in a host country.[3] The impacts have not as yet been quantified, but in principle can be identified as degrading influences on the quality of the coastal zone. There is an increase in noise and atmospheric pollution, primarily from transportation — automobiles, trucks, airplanes and ships. Tourists contribute wastes which may overtax sewer systems or despoil harbors through inadequate disposal systems on pleasure craft.

WASTE ACCOMMODATION

It is now nearly forty years since scientists recognized that uncontrolled releases of societal wastes to the coastal ocean can cause irreparable damage to both public health and the integrity of communities of organisms. The awareness developed with concerns about the large amounts of artificial radio nuclides being produced at nuclear energy facilities and about the increasing usage of chlorinated hydrocarbon pesticides in agriculture and disease prevention. Policies were developed in northern hemispheric countries to strongly regulate the entry of such substances into the environment and monitoring programs were instituted to insure compliance with existing statutes.

In the 1970s environmental groups and government regulatory agencies became involved with toxic substances. Initially they had strong ties to the scientists and engineers, but with time schisms developed. The scientists worked with observations on the environment; too often the environmentalists and bureaucrats worked with perceptions. Yet the zeal of the latter was able to influence and create public policy most effectively. A mood developed that no wastes from societal activities should be disposed of in the oceans. This sense was translated into various national and international conventions which have had the overall effect of a near-total clamp-down on waste disposal in coastal waters as well as in the open ocean. The oceans were sacred and not to be despoiled — I have labeled this "The Cousteau Mystique."

On the other hand, in the 1980s the countries of the developed world were bewildered by the problems of domestic and industrial waste disposal. Garbage scows were seen on world television traversing the oceans seeking a port in which to discharge their cargoes. Ships loaded with toxic wastes from one country were refused entry into a second country. Economic benefits led some financially distressed developing nations to take as imports wastes from other countries for disposal. This rather unappealing situation led to a treaty, the so-called Basel Convention, which prohibits entry of exported wastes into a country without the government's written consent.

Scientists and engineers had a different stance. They successfully compared the relative merits of land and sea disposal for particular substances in particular sites. They joined with social scientists to identify criteria for rational solutions to problems of industrial and domestic waste disposal.[6] Most important, the oceans were not ruled out as a receiver of the discards.

Assessments of land/sea disposal have been carried out on the bases of the protection of public health and on the integrity of ecosystems. An example of the former involved the disposal of old nuclear submarines.[8] The U.S. Navy possessed in 1984 about 120 vessels, with the great majority to be taken out of service in the next two or three decades. Before disposal the nuclear fuel is to be removed from the reactor compartment of the vessel. There does remain in the structure of the reactor compartment induced radioactivity resulting from the interactions of neutrons with the solids. This structural radioactivity is imbedded within the metal and can be released to the aqueous environment by corrosion processes. The levels of radioactivity are low and can provide a danger only through exposures over long time periods.

Three different strategies were considered for the disposition of the vessels: (1) burial of the reactor compartment at an existing radioactivity disposal site at Hanford, Washington or at the Savannah River Plant in North Carolina. The reactor compartment would be separated from the vessel itself. The non-radioactive remainder would be sunk in deep ocean water or sold as waste metal; (2) the entire submarine, minus the reactor, would be towed to sea and sent to the bottom in a water depth of 2.5 to 3 miles; and (3) a delaying tactic of maintaining the submarine in protective storage at a ship facility. Eventually alternatives (1) or (2) would have to be utilized.

The Navy's evaluation of the three options was based upon resource utilization, impacts upon public health, occupational safety and economics. Land disposal would require 10 acres for 100 vessels, sea disposal 100 square miles. For all three there was no identifiable impact upon ecology. Individual exposures were minimal, although there would be some measurable radiation uptake for shipyard and naval personnel in the third option of protective storage.

The economic factors became important. Land burial or a combination of land/sea burial had an estimated cost of 7.5-13.3 million dollars (in 1981 dollars) per submarine. Sea disposal of the entire hulk (minus the reactor component) was 5.2 million dollars per submarine.

The public response, made evident by lobbying of environmental groups and letters to Congress, was against sea disposal. The moods of members of the U.S. Congress and the Environmental Protection Agency were also unsympathetic. The Navy responded to these pressures and chose the land option. Thus, despite strong economic and environmental arguments, a decision based upon political considerations was made.

There have been other exercises. Multi-media assessments of options for the disposal of sewage sludge and of industrial wastes were carried out in 1984 by a group of 55 social and natural scientists.[6] Biological impacts provided the focus of concern. It was recognized that a single index of impact would be most reasonable for decision makers; it appeared that no such parameter exists or could be devised. The most significant scientific criterion appeared to be the avoidance of species extinction. This was followed by the minimization of habitat loss. The inhibition of the trend toward eutrophication from over-fertilization of coastal waters was a strong influence upon the deliberations.

The following comparisons between land and water disposal provided useful guidance. The ability of a water body to regain a normal community structure following a large waste discharge episode is most difficult for Arctic lands, open ocean and ground water, domains where there can be long residence times for pollutants, centuries to millennia. The study also looked at the relative abilities of waters and lands to contain the pollutants. The waters were uniformly less able to restrict the spread of inputs than many parts of the solid earth. Similarly, the ecosystems on land were deemed easier to repair following damage than aqueous systems. Finally, the return of toxicants and pathogens to society were in general more readily accomplished via aqueous systems than those on land. The criteria to assist in the decision making process were both broad and sophisticated.

In the case of sewage sludge disposal, public perceptions, regulatory considerations, available technology, environmental risks and economics did not bias a conclusion toward either option. Similarly, for the disposal of titanium dioxide production wastes, primarily iron oxides and acids, the environmental and economic arguments favored ocean discharge, whereas the institutional parameters were less inclined toward this alternative. But what is important in these studies is the conclusion that ocean disposal can be at least as attractive as land disposal to an interdisciplinary group of scholars.

Marine scientists and engineers in advanced societies possess or can obtain the appropriate information upon which to assess the disposal of societal wastes on a multi-media basis. The perceptions of some governmental bodies, strongly influenced by environmental groups, view the use of the oceans for waste space as heretical. However, increasing populations, coupled with dwindling land disposal sites, will bring into play the economics of the problem. Rational behavior may then lead to a slow return to some controlled coastal ocean disposal.

MARICULTURE

Perhaps the fastest growing activity in the coastal zone is aquaculture, the farming and herding of organisms. It accounts for about ten percent of the world harvest of fish and shellfish.[11] It is dominated by freshwater finfish culture, but mariculture activities are clearly on the rise (Table 3). For example, the cultivation of crustaceans on a worldwide basis increased nearly ten-fold between 1975 and 1985. Mariculture products are the base of a strong export market in many countries. The nations that are the major producers may not be the major exporters (Table 4). Mariculture of such organisms as shrimp and salmon has become so effective that market prices have declined dramatically in recent years.

Table 3

Summary of Estimated Aquaculture Production by Region in 1985 (thousands of metric tons)

Region	Finfish	Crustaceans	Molluscs	Seaweed	Other	Total
Africa	60.6	0.1	0.4	0.0	0.0	61.1
North America	197.8	33.8	160.8	0.2	0.0	392.6
South America	28.5	32.9	1.9	4.9	0.0	68.2
Asia & Oceania	3793.8	198.6	2140.5	2767.6	28.3	8928.8
Europe	340.8	0.0	495.0	4.5	0.0	840.6
USSR	296.0	0.0	0.0	0.0	0.0	296.0
Total in 1985	4517.5	265.7	2798.6	2777.2	28.3	10587.3
Total in 1975	2628.8	29.7	1961.2	na	na	na

na: not available

Source: Rhodes, 1989.

Table 4

1987 Statistics on Bivalve Mariculture

	Clams	Mussels	Oysters
Major Producer	China	Spain	Korea
Amount in Metric Tons	889,951	206,706	303,223
Major Exporter	China	Netherlands	Korea
Amount in Metric Tons	13,483	45,668	6228
Major Importer	Japan, Thailand	France	U.S.

Source: Mollusc Farming, 1990

There are two classes of mariculture: farming and ranching. In the former case the organisms are maintained in enclosures of one type or another, pens or semi-enclosed water bodies such as mangrove swamps or small embayments. The farmer usually provides the food for the organisms. In ranching, young fish are introduced into rivers or estuaries from which they enter the open ocean. Naturally existing prey offer primary sustenance for the fish. Three products dominate mariculture: seaweed, shrimp and salmon. Asia is the major culturing region for seaweed, with the principal use being human consumption.[11] Japan is the larger producer, followed by Korea, Philippines and China.

Shrimp have become one of the most valuable maricultured organisms. Twenty-six percent of the world's supply came from maricultured organisms in 1989.[12] The Asian region produces the largest quantity, followed by Latin America. The People's Republic of China, Indonesia, Thailand and the Philippines are the major producers in Asia, followed by Equador in Latin America.

Salmon has its major production through farming in western Europe. Norway accounts for nearly 90% of the world's production. In salmon farming the fry are hatched from eggs and grown in troughs, tanks or raceways. They are transferred to fresh water enclosures and maintained there until they are ready for entry to cages or tanks with salt water. This takes about 30 months. At this time they are called smolts. In salt waters their growth rates are much higher and they achieve marketable weights of 1.5-2.10 kg (grilse). With a further year's growth they achieve weights of 2-3 kg. for males and 5 kg. for females.

In salmon ranching, the effectiveness depends upon the ability of the fish to return to their release sites after spending time in the open ocean, sometimes at distances of thousands of kilometers. A one percent return represents the break-even point, although a two percent or more recovery has been observed.

There are several circumstances which make farming unattractive. For example, overproduction has threatened continued expansion. The surge in output of Norwegian salmon has reduced the minimum price to an extent that it is sometimes below the cost of production. In Japan, the farmed salmon now claim a larger share of the market than those captured in the wild. As a consequence, salmon fishermen have suffered employment losses.

The interactions with the environment have positive and negative aspects. Farm enclosures, for example, offer wild fish a novel environment in which there is available food, the uneaten materials offered to the farmed organisms, or the encrusting organisms that grow on the structural components.

Then there is the problem of over fishing of some wild species to satisfy the dietary requirements of the more valuable farmed products. One ton of fish meal is required to produce one ton of salmon. In the United Kingdom, salmon mariculture utilizes about 5% of fish meal production. Although at the present time there is no evident impact on the populations of fish involved in meal production, future expansion of mariculture might alter the present situation and lead to over fishing.

Two general problems are generated by mariculture itself. First, there is the loss or undesirable alteration of natural habitats. Shrimp farms in mangrove environments can bring about degradation or destruction of this habitat. The excessive entry of plant nutrients from fish farms through decaying food or metabolic wastes leads to eutrophication. China's Llaoning Province, with 5,200 acres of shrimp ponds, was struck by red tides in August 1989. Mortalities of 30-40% were observed.[12] There is also the worry of commercially grown shellfish consuming red tide organisms and transmitting to humans toxins such as those associated with Paralytic Shellfish Poisoning.

There are the problems with the therapeutants upon non-target organisms. Marine mariculture is a form of monoculture and as such as subject to crop failures due to invasions of predators, especially microorganisms. In 1988 the black tiger shrimp devastation in Taiwan may have been a consequence of such a phenomenon. To minimize the possibility of such a disaster, powerful antibiotics such as tetracycline and streptomycin have been introduced into the food or waters at the mariculture sites. Levels of these substances in commercially sold products are yet to be systematically measured. Also, anti-foulants such as copper containing compounds and the tributyltins have been applied to both pens and nets. These terribly toxic substances can impact non-target organisms living in the vicinity of the mariculture system.

TRANSPORTATION

The use of the coastal ocean as a participant in the movement of ships, trains and vehicles through its ports and underground tunnels will put additional demands upon coastal space with rising tourism and trade.

Tunnels have been constructed in Japan to lengths of 54 km, and one across the English Channel connecting England with the European continent is now being built. The longest one, Sekan Under Sea Tunnel, connects Hunshu with Hokkaido, Japan. Also completed in Japan are the Kanmon Under Sea Tunnel (3.6 km) and the New Kanmon Under Sea Tunnel for the bullet train connecting Honshu and Kyushu.[5] Also, there is the planned construction of the Huoyo Strait Tunnel (40 km), bridging Shiukoku and Kyushu.

The conflict of undersea tunnels with other users of coastal space will involve primarily the land areas needed for entry and exit. However, the information gained in the construction and operation of tunnels can be applied to other anticipated uses of undersea coastal space: industrial plants, habitation, and storage. The vertical dimension of coastal zone space will increase in importance with time.

An increase in transocean shipping will rise due to the increasing world population, demanding more materials and energy

to achieve higher life styles. For those countries either exporting or importing high-volume, low-cost commodities such as coal, oil, timber, and wheat, large bulk ocean traversing carriers (150,000 dwt or more) appear to be essential.[7] At the present time such large vessels are primarily involved with the transport of petroleum and petroleum products. However, appropriate deep-water ports to handle such vessels are lacking, especially in those developing countries which are currently unable to accommodate the super-tankers. The development of such ports will require that harbors be deepened and subject to extensive and continuous dredging. Alterations to life processes in and surrounding the port area can be expected — fishing and nursery grounds for fish can be changed or eliminated. Dredging itself can interfere with sediment transport processes. Finally, increased ship loading and unloading can place additional stresses upon space in the port vicinity.

OVERVIEW

In order for coastal zone space to maintain its quality and utility to its users and to the public, those responsible for its management must pay constant and vigilant attention to possible degrading impacts. Tourism is economically the most important activity; it can be affected adversely by improper waste husbandry. On the other hand, the coastal ocean is underused as a waste receptacle. Multi-media assessments are crucial to ascertain the most reasonable disposal sites on scientific, economic, social and engineering bases. Mariculture continues to grow and efficient practices have reduced the prices of some sea products, yet environmental impacts are more and more evident and should be eliminated. Finally, more extensive use of the coastal zone in transportation, either through shipping or through tunnels, most probably will come about. Again, unacceptable interferences with biological and geological systems are to be minimized.

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Clean-up, Conservation and Enhancement of the Coastal Ocean: A Confusion of Priorities

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ABSTRACT

While large expenditures are being made, or contemplated, to attempt to clean-up severely degraded areas of the coastal ocean in the United States and in other developed countries, other healthy areas — often parts of these same coastal systems — are being degraded because of a failure to put in place appropriate environmental safeguards. And there is an imminent threat of enormous losses of coastal resources in developing countries over the next two decades because of unrestrained population growth.

Our priorities for clean-up, conservation and enhancement of the coastal ocean need to be reordered. The first priority should be to conserve those areas that are in good condition. The second priority should be to rehabilitate those areas where an investment would result in predictable and significant enhancement of the ecosystem and of uses and values important to present society and to future generations. The third priority should be to tackle those areas of the coastal ocean that have been severely impacted by society where major investments will be required with uncertain payoffs to the environment and to society. These priorities need not be pursued seriatim; indeed in many cases they should be done in parallel.

Clear statements of goals and objectives for the coastal ocean, and priorities and strategies for attaining them are necessary if we are to significantly improve our record of conserving and, when necessary, rehabilitating the coastal ocean. Preventive environmental medicine is far cheaper and more effective than attempts to rehabilitate severely impacted areas. If we are to avoid devastating impacts on the world's coastal oceans by the burgeoning populations of developing countries, developed countries will have to lead by example at home and be active in providing financial and technological assistance abroad.

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In this paper, I discuss the global population problem, describe the priority problems — past and prospective — of the coastal ocean and offer some suggestions for dealing with them more effectively.

POPULATION GROWTH AND THE COASTAL OCEAN

There has been an explosive growth in the world's population over the past 2000 years. In the year 1 A.D. the world population was roughly 250 million. By 1850 A.D. it had grown to 1 billion and by 1950 A.D. to 2.5 billion. Between 1950 and 1987, the population doubled from 2.5 to 5.0 billion. The Earth's population increased as much in this 37 year period as it had in the previous 1.5 million years, or more, since humans first appeared. Of the 5.3 billion people who now inhabit the Earth, over 40% are under the age of 15. Thus, the stage is set for a continued mushrooming of the world's population.

Throughout the world, half of humanity now lives in coastal areas. The United States is no exception. According to Bureau of Census data, in 1988 about 53% of the United States population lived within 50 miles of the coast of the oceans and the Great Lakes. The number and percent are increasing. Between 1950 and 1980 the people living in coastal counties directly adjacent to marine waters almost doubled and is continuing to increase. By the year 2010 the United States coastal population is expected to grow from 80 million to more than 127 million — an increase of almost 60% nationwide. Within the United States, the Northeast and Pacific regions have the largest coastal populations. The Northeast region, which is defined as extending from Virginia to Maine, accounts for more than one-third of the total United States population. It contains 18 of the 25 most densely populated counties in the United States and 9 of the top 10; 63% of the Northeast region's population lives within coastal counties. The northeast contains 6 of the 7 leading states in coastal county population.[1]

The United Nations estimates that by the year 2055 the Earth's population will increase from 5.3 to 8.5 billion before stabilizing at over 10 billion at the end of the next century. Ninety-five percent of the world's projected population growth over the next 20 years will come in developing countries, particularly in Africa, Asia and Latin America. Much of the growth will come in coastal areas. These countries are not equipped to deal with the wastes of their burgeoning populations. Of all the wastes, human sewage perhaps poses the greatest threat to the coastal ocean. Unless decisive action is taken now, much of this sewage will find its way into the coastal ocean raw; most into nearshore areas, including estuaries. The human pathogens will lead to major threats to human health through consumption of contaminated fish and shellfish and through direct exposure during swimming and bathing. The increases in the levels of nutrients may lead to eutrophic conditions, particularly in estuaries, bays and lagoons and to hypoxic or anoxic conditions. The impacts on human health, on ecosystem health and on fisheries may be catastrophic.

The 10 most populous countries of the world are listed in Table 1; the 10 most rapidly growing countries in Table 2. It is, of course, not only the total population that counts but how that population is distributed — the degree of urbanization and the population density. The 10 most urbanized countries are listed in Table 3 and the 10 countries with the highest population densities in Table 4.

Table 1

The 10 Most Populous Countries

Country	1988 Population in Millions
1. China	1,104.00
2. India	796.60
3. USSR	283.60
4. USA	246.33
5. Indonesia	174.95
6. Brazil	144.43
7. Japan	122.61
8. Pakistan	105.41
9. Nigeria	104.96
10. Bangladesh	104.53

Table 2

The 10 Fastest Growing Countries

Country	% Average Annual Increase, 1983-88
1. Macao	5.9
2. Burkina Faso	5.8
3. Saudi Arabia	5.6
4. Kenya	4.9
5. Bahrain	4.8
6. Kuwait	4.5
7. Cote D'Ivoire	4.5
8. UAE	4.4
9. Liberia	4.2
10. Qatar	4.1

Table 3

The Top 10 Countries in Degree of Urbanization

Country	%Urbanized (1985)
1. Macao	100.0
2. Singapore	100.0
3. Belgium	96.3
4. Kuwait	93.7
5. Hong Kong	92.4
6. UK	91.7
7. Israel	90.3
8. Iceland	89.4
9. Netherlands	88.4
10. Qatar	88.0

TABLE 4

The 10 Countries With The Highest Population Densities

Country	Population Density (People/km2)
1. Macao	25882.3
2. Hong Kong	5,308.4
3. Singapore	4,288.0
4. Bermuda	1,132.1
5. Malta	1,076.0
6. Bangladesh	725.9
7. Bahrain	694.6
8. Mauritius	591.4
9. Barbados	580.0
10. Taiwan	552.8

THE PRIORITY PROBLEMS

In their most recent report, the Joint Group of Experts on Scientific Aspects of Marine Pollution (GESAMP)[2] reported that for the world ocean the major pollution problems of concern were, in decreasing order of importance:

- nutrient contamination
- microbial contamination of seafood
- disposal of debris (particularly plastic debris)
- occurrence of synthetic organic compounds in sediments and in predators at the top of the marine food chain.
- oil in marine systems; the main global impact is tar balls on beaches and the

effects of spills in local, sheltered areas.
- trace contaminants such as Cd, Pb and Hg in areas where they are discharged in high concentrations.
- radioactive contamination — because it is a public concern.

The GESAMP report does not consider the last three issues to be particularly important globally, but points out that locally oil and trace contaminants can be problems. One wonders if the recent oil spill in the Persian Gulf would change the level of their concern about oil spills. The GESAMP report observes that while "man's fingerprints" are found everywhere in the World Ocean, the imprint varies dramatically from place to place. According to this group of experts, the open ocean is still "relatively clean," but they express concern that too little is being done to "arrest or anticipate situations that call for action." They express particular concern for coastal areas in stating "... not enough consideration is being given to the consequences of coastal development ... actions on land continue to be taken and executed without regard to their consequences in coastal waters."

The Executive Summary of the GESAMP report closes with this observation

> In summary, at the end of the 1980's the major causes of concern in the marine environment on a global basis are coastal development and the attendant destruction of habitats, eutrophication, microbial contamination of seafood, fouling of the seas by litter, continued build-up of chlorinated hydrocarbons, especially in the tropics, and the sub-tropics, and accumulation of tar balls.

The coastal states of the United States come to similar conclusions as to the major threats to the coastal ocean of the United States. In their 1988 State 305(B) reports to the U.S. Environmental Protection Agency,[3] the 23 States, Jurisdications and Interstate Commissions report that the major causes of degradation of their estuarine waters to the extent that they no longer support the designated activities are:

- nutrients which account for 50% of the total (aggregate) impaired area;
- pathogens which account for 40% of the total (aggregate) impaired area;
- organic enrichment which accounts for 29% of the total (aggregate) impaired area because of low levels of dissolved oxygen.

(Note: The reason that the total is greater than 100% is that the designations of impaired areas associated with various causes are not mutually exclusive.)

In the 1988 State 305(B) reports,[3] the single most important source of pollution cited was municipal discharge which affected 53% of the total impaired area.

The GESAMP report goes on to observe ". . . in view of continuing growth of human populations, we fear that the marine environment could deteriorate significantly in the next decade unless strong coordinated national and international action is taken now. The efforts will be great and the costs high, but nothing short of that will ensure the future of the seas."

Clearly, the time to act is now. Most of the coastal areas which will experience the greatest population growth can be identified now. The impacts of the burgeoning population on the ocean will be greatest on the coastal ocean, particularly on estuaries and other semi-enclosed coastal water bodies. While the costs to take preventive measures would be high, the costs of delaying will be enormous. If action is to be taken, it will require the sensitive leadership of developed countries. Appropriate wastewater management strategies and technologies and land use practices are essential. These must be consistent with the local culture, the abilities of the workforce, and the economies of the affected countries. While 95% of the projected population growth will come in developing countries, they do not have the resources to deal with their problems effectively. As Samuelson[4] has observed "Pollution seems to be a mere inconvenience next to poverty and disease." That will continue to be the case.

CONSERVATION OR CLEAN-UP: A CONFUSION OF PRIORITIES

Whether in the United States, in other developed countries, or in developing countries, the first priorities should be to identify those areas of the coastal ocean that are still in good condition, to state explicitly what values — including ecosystem values — and uses society wants for those areas now and in the future and then to take whatever steps are required to ensure that they are adequately protected. Preventive environmental medicine is a far more effective and economical strategy than restorative environmental medicine. Peter Drucker, the management specialist, once observed that long-range planning does not deal with future decisions, but rather with the future of present decisions. The decisions we make now will determine the future of the world's coastal ocean for decades to come.

In the United States, and elsewhere, steps should be taken now to guide — not stop, but to guide — development of coastal areas to ensure that critical habitats, both terrestrial and aquatic, are conserved, that the ecosytem is protected, that public access is enhanced and that uses and values important to present and future generations are preserved and, where necessary, restored. Special attention should be directed at revitalizing coastal towns and cities which are in decline and whose residents are moving to undeveloped coastal areas. Retention and revitalization of coastal communities are environmentally sound practices and should be promoted.

On the land side, zoning, clustering, setbacks, greenways, buffer zones, transfer of development rights, acquisition of open space and all the other tools and techniques of planners should be employed to ensure that those coastal marine areas still in good condition are conserved and that over time those areas that do not meet society's desired values and uses are rehabilitated. In making these judgements, we must not overlook the value of ports, shipping, and other water-dependent activities.

Efforts at zoning should not be restricted to the land. They should be extended to the water. While it is more difficult to zone estuaries and other coastal water bodies because of the mobility of the fluid medium than it is to zone the terrestrial environment, the difficulties of zoning the marine environment have been overestimated and the difficulties of zoning the terrestrial environment have been underestimated. Groundwaters and surface waters have been contaminated because of poor waste management practices on land. Large estuarine systems with complicated geometries and numerous tributaries are particularly amenable to zoning; estuarine systems like Chesapeake Bay and Long Island Sound. Other estuaries, like the Delaware Bay estuary whose water-dependent activities are distributed in distinct zones along the estuary, are also amenable to zoning.

Zoning of estuaries and other coastal water bodies must obviously be compatible with their natural features and with important ecosystem functions. Not even master planners like the late Robert Moses and Lee Koppelman can shift the spawning and nursery activities of anadromous species to segments that do not match their biological requirements. Much of the zoning of human activities is already in place, particularly in urbanized estuaries. It is unlikely that any major ports will be moved. In these cases, zoning would be an affirmation of the importance of ports, a legitimization of this use of these segments of the marine environment and the promulgation of strategies — policies and practices — that accommodate the need for periodic dredging and disposal of the material dredged without prolonged, costly delays.

In 1976 Schubel[5] called for zoning estuaries into a number of segments in which different water quality standards and criteria would be applied; standards and criteria consistent with the natural processes that characterize the system and with the uses and values — present and prospective — considered to be most important by society. Schubel pointed out that the first step, and the most difficult, in the zoning process is the assignment of priorities to uses and values. This must be done through a broad consultative process.

Schubel[5] observed "Effective estuarine zoning must not only take into account present and potential uses of a particular segment but must also recognize existing uses of the contiguous coasts." Zoning of estuaries and other coastal waters and the adjacent land areas should be done in concert. It is clear that the quality of nearshore coastal environments is primarily a result of land-based activities. While the land areas immediately adjacent to the coast usually have the greatest influence on the marine zone, the zone of terrestrial influence on nearshore environments is large, often extending for hundreds of miles throughout the drainage systems of major rivers. Nowhere is this coupling of activities in the drainage basin to water quality in the estuary clearer than the coupling of the drainage basin of the Susquehanna River to the upper Chesapeake Bay.

In addition to protecting those coastal environments that are still in good condition, society should determine which environments it wants cleaned up and restored. The strategies to achieve those societal goals and objectives should be based upon the best, the most rigorous, scientific, technical and economic analyses of the full range of alternatives. If the selection among alternatives is to be made democratically, everyone should have the best assessment of what they are buying before the decision is made. The costs and expectations should be made widely known and a carefully crafted environmental monitoring program should be implemented to track progress in achieving the explicit goals and objectives. The results should be reported publicly to provide an assessment of the efficacy of the management strategies selected.

Let's look briefly at an example of conflicting priorities of conservation and clean-up, Long Island Sound.

Long Island Sound

Long Island Sound is characterized by a steep gradient in water quality along its axis reflecting the strengths of inputs of wastes and the natural features of the circulation. In the western Sound, near New York City, where inputs of nutrients and contaminants from treatment plants, combined sewer overflows and other point sources are largest, water quality is degraded. In the summer, bottom waters in the western Sound often are diminished and sometimes even depleted of dissolved oxygen. Beaches and shellfish beds throughout this segment of the Sound are closed because of intermittent high values of coliform bacteria. Because of the inputs of wastes and the natural estuarine circulation pattern, the bottom of the western Sound is lined with a deposit of fine-grained, organic-rich, contaminant-laden sediments. Within 25 kilometers to the east, water quality improves dramatically and continues to improve to the eastern end of the Sound in the Race. Environmental problems in the Sound are concentrated in the western Sound and in the embayments along its northern and southern shores in Connecticut and New York. The remainder of the Sound is in good to very good condition.

The Long Island Sound Study selected hypoxia of the western Sound as the most serious problem that needs remediation. The study indicated the primary cause of the eutrophication that leads to hypoxia is nitrogen loading and estimated that about 50% of the nitrogen comes from anthropogenic point sources. The point sources of nutrients, large sewage treatment plants, and the point sources of contaminants are concentrated in the western Sound. Most direct inputs of wastes to the western Sound are stable or declining. The City's population is static or decreasing. The City's treatment plants are being brought into compliance with the requirements of the Clean Water Act. The Combined Sewer Overflow Abatement Program is proceeding. Inputs of industrial wastes continue to decrease as industry leaves the City and as industrial pretreatment programs come on-line. Because of these activities, the inputs of wastes and the signal from New York City will continue to decrease.

While the sources of stress on the western Sound are declining, the sources of stress on the central and eastern Sound are increasing. Population in areas contiguous to the central and eastern Sound is growing, although much more slowly than in the past several decades.

There continues to be great public pressure to concentrate clean-up efforts on the western Sound and on metropolitan New York City sources of nutrients — large publicly owned treatment plants. The estimated cost is high, in the billions of dollars, and the environmental benefits marginal.

Fortunately, the Long Island Sound Study Management Committee of the National Estuary Program has recommended capping the inputs of nutrients to the central and eastern Sounds and taking a fiscally conservative approach to upgrading nutrient removal at large treatment plants in the western Sound.

There will continue to be pressure to invest billions of dollars to upgrade the City's treatment plants without a rigorous scientific basis for establishing the anticipated environmental benefits and without an assessment of alternatives for reducing eutrophication and hypoxia.

If slight gains in environmental quality in the western Sound are offset by losses in the central and eastern Sound, the net change to the Long Island Sound ecosystem, as a whole, may be a loss. A better strategy would be to put in place management strategies to prevent degradation of the central and eastern Sound. Because of the estuarine circulation of the Sound, any strategies that improve the central and eastern Sound will also benefit the western Sound.

CONCLUSION

In Aesop's Fable of the Two Crabs, when the mother crab and her youngster take a walk along the beach, the mother admonishes her offspring to walk straight forward, rather than sideways because walking sideways looks so awkward. The young crab tells her mother that if she would set an example, she would surely follow it. Over the years there have been two interpretations of this fable. The first, and most obvious is that it is important to set a good example if we expect a change in behavior. A second interpretation is that one should never expect others to do things for which they are incapable of setting a proper example.

It is clear that we should take steps now to ensure that those portions of our environment that are still in good condition are conserved. It is also clear that can happen only if developed countries take the lead in assisting developing countries. One component of effective leadership is setting a good example. The United States is still walking sideways.

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Managing Multiple Use in U.S. Coastal Public Trust Waters

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ABSTRACT

In the last twenty years there has been a dramatic increase in the use of coastal and ocean waters. This use will continue to grow if current trends remain the same. Given the finite nature of coastal and ocean space, increased use means more contact between resource consumers and more contact generally leads to greater conflict.

Nearshore coastal waters have been the first areas to feel the stress. There is conflict between industrial uses and uses that depend on a clean environment, between recreational and commercial fishermen, and between tourist oriented shoreline development (with its associated aquatic activity) and other more traditional uses. Because of these conflicts jurisdictions are searching for new management strategies.

This paper summarizes a project that was completed in November, 1990 and funded by the U.S. Environmental Protection Agency through the Albemarle-Pamlico Estuarine Study (AP). The project's goal was to identify a management strategy that would better protect public trust rights and uses in North Carolina's coastal waters. The strategy involved the development of a model water use plan for Carteret County. The final project report, "North Carolina's Estuaries: A Pilot Study for Managing Multiple Use In the State's Public Trust Waters," combines legal analysis, inventories of aquatic resources and uses, policy development and GIS computer modeling. It is the author's hope that the strategy developed through this project will aid other jurisdictions in coping with the problems associated with the demands for coastal and ocean space.

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PUBLIC TRUST RIGHTS AND USES

The concept of public trust has ancient origins. Roman law held that "[b]y the law of nature" certain resources were considered "common to all:" air, running water, sea and shores of the sea. Old English common law, from which much of the law in the United States evolved, allowed the King to own the beds of navigable waters, but gave the public the right to use the water. The American idea of public trust holds that the individual states own the tidelands and their associated resources, but hold them in "trust" for the people.

North Carolina adheres to this concept by recognizing public or state ownership of land covered by tidal waters. All the water that covers this land (seaward to the end of state jurisdiction at 3 miles), as well as navigable water covering non-tidal lands, is also within the public trust. Consequently, citizens of the state enjoy the right to use public trust land and water. These rights, called public trust rights, include the right to navigate, swim, hunt, fish and enjoy all recreational activities in the water, courses of state and right to freely use and enjoy the state's ocean and estuarine beaches and public access to the beaches.

State Law and the Public Trust

In 1974 North Carolina passed the N.C. Coastal Area Management Act (CAMA) in conformity with the Federal Coastal Zone Management Act of 1972. CAMA recognizes that the state's coastal area is being subjected to pressures "which are the result of the often conflicting need of a society expanding in industrial development, in population and in the recreational aspirations of its citizens...." The act clearly states that the management of water areas, especially estuarine and public trust waters, is important in achieving the balanced use and preservation of the state's coastal resources.

CAMA designated public trust waters and estuarine waters as Areas of Environmental Concern (AECs). These are coastal waters with resource values and environmental qualities sufficient to warrant special protection. Protection for AECs is provided in two ways. The Act creates a regulatory program for each area and requires permits for development activities within the boundaries of the zone. Secondly, and more pertinent to this discussion, the Act contains a strong directive for coastal area planning.

CAMA requires local governments within the coastal area (20 counties that border on the Atlantic Ocean or a coastal river or sound) to develop land use plans based on general guidelines. The plans are intended to provide a mechanism for local governments to establish their own development priorities within the framework of state guidelines. To date, however, CAMA mandated plans have only addressed land uses. This is true even though the jurisdictional boundaries of several counties encompass large areas of coastal waters and there is no prohibition (statutory or regulatory) forbidding water use planning. This void, coupled with conflicts growing from increasing demands for coastal and ocean space, led to initiation of the project.

BENEFITS OF WATER USE PLANNING

Several benefits can be derived from using comprehensive water use planning. First, planning can provide predictability for all users of the state's public trust waters and adjacent shoreline. For example, environmentalists generally want a long-term commitment to protection of public trust waters while developers want to know what development is possible before they make major investment decisions. It has not been uncommon for developers to find their plans for construction (for marina complexes, for example) thwarted when they base decisions on allowable land uses without considering the resources in adjacent waters. Effective water use planning would provide information regarding aquatic resources (submerged aquatic vegetation, for example) that could guide decisions regarding shoreline and in-water development.

In this same light, comprehensive water use planning provides a wholistic view of the land and water interface — a view that can consider inter-relationships between functional (jurisdictional) and natural systems. Too often, management strategies are built around jurisdictional considerations without integrating the natural systems for which the strategy is intended to protect or enhance. Water use plans can act as a collecting point for all existing federal, state and local law, regulations and policies. A frequent criticism of management programs is that they are often disjointed and confusing, making it difficult for resource users to determine their legal responsibilities. A properly structured water-use plan could alleviate some of this confusion.

Finally, plans can act as collecting points for new research information. Plan policies and any attendant regulations can be updated or changed to accommodate new information.

THE LEGAL FOUNDATION FOR WATER USE PLANNING

A local water use plan and any attempt by local government to regulate public trust waters must not be in conflict with existing state or federal laws and regulations. Local plans and ordinances must interact with and, in some cases, refine existing law.

Consequently, the AP study began with an analysis of all local, state and federal resource management laws and regulations that apply to the public trust waters of Carteret County, North Carolina. A thorough discussion of these laws and regulations is too extensive for this space. Suffice it to say, that the discussion covers federal and state laws applicable to water quality, coastal development, fisheries, boating safety and sanitation, and navigation.

There is one state law, however, that should be mentioned. In 1983 the state legislature gave coastal counties the power to regulate development over public trust estuarine waters within their jurisdictional boundaries. This delegation is representative of a trend in North Carolina away from strong state-mandated environmental regulation to greater local involvement. Local governments have been slow to adopt regulations that apply to their jurisdictional waters.

THE WATER USE PLAN

Carteret County was chosen for the model plan because it is a region experiencing intense public trust conflicts. In part, these conflicts have arisen because of the area's rich fishery resources and recreational attributes. Increased recreational use in and around public trust waters has put pressure on some of the more traditional uses — particularly shellfishing. Also the county contains the towns of Beaufort and Morehead City. Beaufort has rapidly become one of the South Atlantic's favorite boating points because of its charm, proximity to the Intracoastal waterway, docking facilities and good sailing. Morehead City is one of the state's two largest ports — a fact that could become more important if oil and gas are discovered off North Carolina's coast.

Key Growth and Water Use Indicators

The preparation of the Carteret County Water Use Plan required an analysis of certain key growth and water use indicators. The intent of the analysis was to insure that the policies contained in the plan responded as closely as possible to current trends and issues facing the planning area. The key growth and water use indicators were grouped as follows:

Population
Housing
Tourism
Commercial Fishing
Recreational Fishing
State Ports Authority Activity

Collectively, these indicators summarize past and present growth and water use trends in Carteret County, and provide a base from which to measure future conditions in the planning area. Basically, the indicators show a large increase in population (almost three times that of the state), a substantial increase in housing — particularly seasonal housing (from 1980 to 1987 seasonal housing units increased by 71 percent) and substantial increases in tourism. From the perspective of fishing and seafood, it should be noted that Carteret County has historically dominated the commercial fishing industry in the state. Trends show this dominance beginning to falter — perhaps because of the increase in other uses. Marina development and recreational boating has increased significantly.

Policy Statements

The policy statements in the Water Use Plan serve as the basis for future decisions on land and water development proposals. They also provide local government perspectives to state and federal agencies regarding the county's policies toward water use.

Policy statements in the plan are grouped into three major categories: Policies for resource protection; Policies for resource production; and Policies for other public trust water uses. The policies for resource protection include the subjects of water quality, coastal wetlands, primary and secondary nursery areas, shellfish areas, submerged aquatic vegetation, cultural and historic resources, land use and development and special area plans and programs. The policies for resource production include the subjects of commercial and sport fisheries, aquaculture and mineral extraction. Included in the policies for public trust water uses are water dependent uses, marinas, dry stack boat storage, private use of public waters, harbor management planning, waterways, public access, floating structures, and military restricted areas.

Plan Implementation

A water use classification system was developed as a means of assisting in the implementation of the policies adopted by the county. By delineating water classes on a map, local government and its citizens can specify those areas where certain policies will apply. It must be emphasized that water classification is merely the tool to help implement policies and not a strict regulatory mechanism. The designation of water classes allows the county to illustrate its policy statements as to where and at what intensity water use activities should occur, and where natural resources should be conserved.

The County's public trust waters were divided into water management areas. A management area is a discrete geographic area defined by physical, biological and cultural characteristics within which certain management objectives and priorities are promoted or encouraged. Each management area was assigned a classification which defines a management objective and provides a general policy framework for the area. The water area classification system consists of three management classes: Preservation, Conservation and Developed.

Preservation water areas are those areas that are needed to assure the protection of significant fish and wildlife habitats. These are to be managed to preserve the natural resources in recognition of dynamic natural, geological and evolutionary processes. Permissible uses in these areas would include low-intensity water-dependent recreation, research and educational observation.

Conservation water areas are those areas needed for recreational and aesthetic uses, aquaculture and fishing. Consequently management should be for long-term productivity of the area to insure its continued availability for these uses.

Developed water areas are designated to provide for navigation and other identified needs for public, commercial and industrial water dependent uses. These areas include deep water areas adjacent to or in proximity with the shoreline, navigation channels and areas of minimum biological significance needed for uses requiring alteration of the estuary.

Factors Used in Characterization of Water Area Use Classifications

The factors listed below describe the prevailing characteristics which are associated with each of the three water area use classifications. In characterizing each area, it was not expected that a given area would meet each and every factor. Rather, it was the combined "weight of the evidence" that was examined.

In some instances, the presence of only one factor was determinant. For example, a maintained turning basin qualified an area as developed regardless of how many other developed characteristics were present. Similarly, a large primary nursery area qualified an area as preservation despite the presence of several other development-like characteristics within the area. In other words, determinate factors represent uses or resources that are associated with specific water areas and are considered important enough to cause that area to automatically fall within one of the classifications. In areas where the determinate factors are absent, it was a combination of the non-determinant factors that dictated the classification.

A computer model was developed to assess the determinant and non-determinant factors and to assign classifications to the public trust waters. The model was implemented using the Geographic Information System (GIS) that is operated by North Carolina's Center for Geographic Information and Analysis (CGIA). CGIA builds and maintains a database of digital geographic data for the state and provides GIS services to federal, state, and local government agencies and to the private sector.

A GIS is a specially designed computer system used to capture, store, measure, display, and analyze spatial data. The GIS provides the capability to make custom maps and to inventory resources, but more importantly, to incorporate spatial analysis into efforts such as water quality modeling, site suitability studies, and trends analysis. Data are stored in the GIS as a series of data layers. One of the capabilities inherent in a GIS is the ability to perform automated map overlays for identification of areas that possess characteristics of two or more data layers. This technique, popularized in manual contact by Ian McHarg (1969), virtually combines two or more data layers in an overlay fashion using the computer.

The GIS model developed for this study was employed to delineate water management areas and to classify the public trust waters of a portion of Carteret County according to the Water Use Classification System (Preservation, Conservation or Developed). The study area included the immediate area of Beaufort and Morehead City.

The detailed process that was employed in developing the model is outlined in the full report.

Table 1

Characterization Factors for Water Area Use Classifications

FACTOR	Preservation Area	Conservation Area	Developed Area
Water quality	SA and ORW	SA and SB	SA, SB, & SC
Adjacent land use	Undeveloped, agricultural with buffers, low density residential	Medium density development	Higher density development
Adjacent CAMA land classification	Conservation or Rural	Conservation, Rural or Transition	Transition or Developed
Water depth	Shallow to deep	Shallow to deep	Generally Deep
Shellfish areas	Generally open and productive, but may be closed temporarily	May be Closed	Permanently closed
Dredged areas	Minimal	Limited	Maintained channels, waterways, basins
Vegetation	Marsh grass, eelgrass, submerged vegetation may be present	Marsh grass, eelgrass, submerged vegetation may be present	General absence of bottom vegetation
Shoreline	Minimal hardening	Limited hardening	Bulkheads, rip rap, etc.
Nursery areas	Primary and secondary	Secondary and none	None
Marinas	Small or few	Few	May be several
Point-source discharges	None or few	Few	May be several
Wildlife or fisheries sanctuaries	May be present	Not present	Not present
Estuarine stream segment	Uppermost reaches	Middle reaches	Lower reaches

Ordinance Development

In North Carolina, and in the United States in general, authority exercised by local government over public trust waters must be based on a grant of power from the state legislature. As mentioned earlier, in 1983 the state legislature gave counties the right to regulate development over estuarine waters and over lands owned by the state and covered by navigable waters. This is an important grant of power that provides local governments with a mechanism to solve some of their own water use conflicts. It is also a power that has yet to be fully used by local governments in North Carolina.

The implementing tool discussed here, ordinance development, is an example of what can be done by a local government, utilizing the water use plan, to regulate marinas in their public trust waters.

First, any ordinance adopted by local government would need to be consistent with existing federal and state statutes and regulations. In addition to statutory law, the ordinance could not violate principles found in case law (for example, the common law principles of riparian rights, public trust rights etc.)

Second, the ordinance would need to be consistent with the policies and water use classifications found in the plan. The policies in Carteret County's model plan that would affect the creation of a marina ordinance are set out below. Note that marinas would be restricted based on the water use classification system developed from the model discussed above.

MARINA POLICIES

Marina Policies Generally

Preferred locations for MARINA DEVELOPMENT shall be in developed water use areas, provided that all other state and federal regulations can be met. The county shall carefully scrutinize marina development proposals in conservation water use areas. New marinas and marina expansions in preservation areas shall be discouraged.

Private Use of Public Waters Policy

Carteret County supports a policy of COST RECOVERY FOR PRIVATE USE of local area public trust waters. The state should apply the proceeds of such recovery to restore and enhance the public trust waters resource within Carteret County.

Floating Structures Policy

Floating structures shall be permitted only in an approved floating structure marina and only when such structure is provided with permanent water and sewer systems approved by the Carteret County Health Department. The county shall develop specific standards for the placement, construction and use of floating structures.

Dry Stack Boat Storage Policy

Provision of private dry stack storage facilities may be allowed adjacent to developed areas to help relieve the demand for publicly financed facilities and to minimize the consumption of public trust surface waters. Proper buffering and fire safety considerations shall be required of all such facilities. Dry stack boat storage shall be discouraged adjacent to preservation and conservation areas.

The plan contains other policies for resource protection that indirectly apply to marinas. They are:

Water Quality Policy

Carteret County shall take no action, nor approve of any action, public or private, which would reduce the water quality classification of local area waters.

Coastal Wetlands Policy

Carteret County shall take no action, nor approve of any action, public or private, which would result in a net loss of coastal wetlands, except in instances of overriding benefit with minimal loss.

Significant Shellfish Areas Policy

Carteret County shall take no action, nor approve of any action, public or private, which would result in a net loss of naturally productive shellfish beds, except in instances of overriding public benefit and minimal loss.

Submerged Aquatic Vegetation Beds Policy

Carteret County shall take no action, public or private, which would result in a net loss of submerged aquatic vegetation beds, except in instances of overriding public benefit and minimal loss.

It is important to remember that the policies and strategies presented above and in the model plan were intended as examples of a planning structure and in no way should be interpreted as specific policy recommendations to Carteret or any other coastal county.

CONCLUSION

To date, coastal planning has been limited to land areas in North Carolina. This is true even though the jurisdictional boundaries of several counties encompass large areas of coastal water and there is no prohibition forbidding the planning process from including public trust waters.

Since North Carolina's Coastal Area Management Act clearly states that the management of water areas is important in achieving the balanced use and preservation of coastal resources and since increasing conflicts are threatening those resources, the project report recommended that the CAMA planning process be expanded to include public trust water. The report also reminded readers that planning must integrate land and water use. Until land and water use are managed in a manner that makes geographic as well as political sense, planning will remain an incomplete response to a tremendous problem.

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Natural Resource Damage Claims Under CERCLA for Ocean Dumping and Marine Pollution

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ABSTRACT

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA or "Superfund") authorizes claims by certain federal, state and local agencies designated as "trustees," for damages to public resources caused by the release of hazardous substances. The President has used his authority under CERCLA to designate the U.S. Commerce Department's Natural Oceanic and Atmospheric Agency (NOAA) as among the federal agencies acting as trustee for oceanic and marine natural resources. In that role, NOAA is charged with assessing and recovering damages for injury to such resources as fish, marine mammals and coral reefs.

The purpose of this paper is to examine how NOAA is presently discharging its responsibility under CERCLA as trustee for marine natural resources and to look at the types of activity NOAA may pursue in the future. The focus will be on a review of its statutory and regulatory mandate under CERCLA. Topics covered will include the scope of investigative efforts, liability of potentially responsible parties for cost reimbursement, measurement(s) of damages, and remedy selection and implementation.

Although CERCLA has been in effect since 1976, only recently has NOAA begun to discharge its mandate as trustee for marine resources. The efforts this entity takes to identify problems, solutions and potentially responsible parties could become a model for use by other nations concerned about the impact of industrial and municipal pollution on oceanic resources.

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INTRODUCTION

The Comprehensive Environmental Response, Compensation and Liability Act (generally referred to as CERCLA or Tacitly)[1] was enacted in 1980 in response to public concern over the need to investigate and clean up major envirommental problems such as Love Canal and Times Beach, Missouri. The objective of this statute was to provide the federal government with funding and enforcement authority to undertake investigation and cleanup of unattended and abandoned hazardous wastes sites and to respond to major spills and releases involving hazardous substances. In the intervening decade, legions of lawyers have argued on behalf of one side or the other in the federal district and appellate courts for and against imposition of CERCLA liability in hundreds of cases involving cost recovery for the cleanup of leaking landfills, abandoned recycling facilities or defunct chemical plants. In these cases, the courts have construed and interpreted CERCLA's liability and damage provisions in an evolving and often unpredictable manner addressing such topics as lender liability,[2] parent and successor corporation liability,[3] and the measurement of damages for cost recovery.[4] The focus has been primarily on either cleaning up hazardous waste sites and recovering the costs from those parties responsible or forcing those parties through judicial actions or administrative orders to undertake the cleanup work.

Included within CERCLA's liability and damage provisions, but largely overlooked until recently, is the authority given to designated federal and state agencies under Section 107(f) to collect damages from those responsible for injury and loss to or destruction of public natural resources incurred as a result of the release of hazardous substances.[5] In response to growing public awareness and concern over environmental catastrophes, such as the EXXON VALDEZ spill off Alaska and the contamination of Boston Harbor and Santa Monica Bay, the government is beginning to turn to Section 107(f) and to focus on monetary recovery, not for the costs of cleanup, but for the injury to or damage and loss of the nation's natural resources. The amounts recoverable in those actions are potentially enormous and the methods employed to evaluate and assess damages often involve novel theories (e.g. loss of use of non-market resources) and employ computer models to generate assessment data.

The purpose of this paper is to examine how natural resources damage claims under CERCLA Section 107(f) are being pursued by federal and state governments and can be used to address environmental harm resulting from ocean dumping and marine pollution. The focus will be on the mechanisms by which CERCLA's provisions governing those claims can be used to recover damages resulting from industrial, municipal and agricultural pollution of marine resources. Other sources of water pollution from sediments and erosion, mine drainage and watercraft wastes are not specifually addressed because they are either exempt or not intended for coverage under CERCLA's provision or are covered by other federal and state legislation.[6] The intent is to review briefly the basic liability and damage provisions of CERCLA and to examine more closely (1) the role of the federal government, (as trustee of certain natural resources), (2) the regulatory procedures for assessing the extent of injury to, destruction of or loss of those natural resources, and (3) the potential defenses and limits on liability available to those targeted.

CERCLA'S BASIC FRAMEWORK

CERCLA establishes a "no fault" strict liability system for dealing with the release or threatened release of hazardous substances from vessels or facilities. The statute allows the U.S. government (typically the U.S. Environmental Protection Agency (EPA)) to either (1) spend allocated dollars from the so-called Superfund to investigate and cleanup releases of hazardous substances from vessels or facilities and then seek cost reimbursement from parties responsible for the release, or (2) compel responsible parties to undertake at their expense the appropriate investigative and cleanup work either by suing these parties for injunctive relief in the federal courts or by having the EPA issue administrative orders authorized under CERCLA directing these parties to undertake the necessary investigative and cleanup effort.[7]

CERCLA identifies four categories of parties (referred to as Potentially Responsible Parties or PRPs) liable under the statute. These consist of the following:

- The current owner or operator of a vessel or a facility,
- Any person who at the time of disposal of any hazardous substance owned or operated any facility at which such hazardous substances were disposed of,
- Any person who by contract, agreement or otherwise directly or indirectly arranged for disposal or treatment of his hazardous substances at a facility owned by another person, and
- Any person accepting hazardous substances for transport to a disposal or treatment facility which he selected and from which there has been a release.

Each of these "covered persons" or PRPs is liable under CERCLA for (1) all costs of removal or remedial action incurred by the federal or state government consistent with the National Contingency Plan (NCP),[8] (2) any other necessary response costs incurred by any other person consistent with the NCP, (3) damages for injury to, destruction of or loss of natural resources, including the costs for assessing such injury, destruction or loss, and (4) costs for having to undertake any health assessment or health affect studies as a result of the release. The amounts recoverable under CERCLA include interest from the date of demand or the date the government incurs the expenditures, whichever is later.

Defenses available to PRPs in cost recovery actions under CERCLA are exceedingly limited.[9] Essentially, a covered person is liable for all costs unless the person can establish by a preponderance of the evidence that the damages caused by the release or threatened release were caused solely by:

- an act of God,
- an act of war,

- an act or omission of a third party with whom the person had no direct or indirect contractual relationship, and then only if it can be demonstrated that the covered person exercised due care and took precautions against the foreseeable acts or omissions of the third party.[10]

In addition to providing these limited defenses, the statute imposes joint and several liability on the covered persons, meaning that any covered person can be responsible for the totality of all environmental damages unless that person can establish that the harm caused by his particular release is divisible and that damages occasioned by the release can be apportioned among the universe of PRPs in some logical manner. Furthermore, it is no defense to a cost recovery action that the release of the hazardous substance which occasioned the need for cleanup was the result of lawful activity at the time it was performed. When one considers that CERCLA statute imposes liability which is joint and several, strict and retroactive, in conjunction with the substantial amount of damages to which persons covered under the act are exposed, the full impact of CERCLA's liability provision becomes apparent to those unfamiliar with its scope.

Procedures for Prosecuting "Cost Recovery" and "Natural Resource Damage" Actions

To recover in an action brought against a PRP (or group of PRPs) for either "cost recovery" or "natural resources damages," the plaintiff must establish the following standard CERCLA elements for imposing liability:

- there has been a release or a threatened release of a hazardous substance from a vessel or facility,
- the release/threatened release has resulted in response costs (or damage to natural resources), and
- the defendant is a member of one of the four groups of covered persons.

There are unique characteristics of "natural resource damage" actions and unique defenses or limits to liability which do not exist in "cost recovery" actions. These will be described further in the sections of this paper dealing with the regulatory framework and potential defenses to natural resource damage claims.

Natural Resources Liability under CERCLA

The pursuit of claims for natural resource damages (which includes the reasonable cost for assessing any such injury, destruction or loss) under CERCLA Section 107(f) of the statute is the exclusive province of the federal or state government or (where jursidiction is appropriate) Indian tribes. There is no private right of action for cost recovery actions under Section 107 such as exists for "cost recovery" actions. The federal or state government designates one or more of their agencies as "trustees" for the natural resources and directs that agency to pursue PRPs for all damages resulting from a release of hazardous substances or the discharge of oil. Amounts recovered can only be used to restore, replace or acquire the equivalent of the natural resources impacted.

Relatively little guidance is provided in the statute as to how damages are to be measured in pursuing claims under Section 107(f). CERCLA notes only that the measure of damages is not limited to the costs to restore or replace any injured, destroyed or lost natural resources, suggesting that damages for loss of or diminution in use and other measures beyond mere replacement costs are recoverable. Section 107(f) expressly prohibits double recoveries under Section 107(a) meaning either that costs associated with investigating both "cost recovery" and "natural resources damages" result in only one recovery or that federal and state trustees pursuing natural resources damage actions cannot each bring separate claims for injury, loss or destruction of these resources. Also, there is express language stating that no recovery is allowable where both the damages and the release of the hazardous substances from which the damages resulted both occurred entirely before December 11,1980, the date of enactment of CERCLA. Finally, the statute specifies an exemption for natural resources damages which were federally permitted or which were acknowledged and tacitly approved by the government when considering the environmental impacts of a project which was required to undergo review and approval under National Environmental Protection Act (NEPA).

The Role of the National Oceanic and Atmospheric Agency Pursuing Natural Resource Damage Claims under CERCLA

Subpart G of the National Contingency Plan designates the various federal agencies assigned to act as federal trustees in prosecuting natural resources damage claims under CERCLA. For land-based resources, the Department of Interior is most frequently assigned responsibility as federal trustee because of its extensive jurisdiction over federal lands, although other agencies, including the Department of Defense and Department of Agriculture, are also designated in the NCP. The National Oceanic and Atmospheric Administration (NOAA), a unit of the Department of Commerce has been designated as trustee for:

> natural resources of navigable waters; tidally influenced waters; waters of the contiguous zone, the outer continental shelf, and upland areas serving as habitat for marine mammals.[11]

This trusteeship includes marine fishery resources and their ecosystems, as well as marine sanctuaries and research reserves.

Before taking action as trustee for these resources, NOAA is to notify and obtain concurrence from any other federal agency charged with managing the particular resource. In addition, NOAA is to coordinate its efforts with state agencies such as the California Department of Fish and Game, the State Lands Commission and the Department of Parks and Recreation. In fulfilling its trusteeship role, NOAA is guided by Natural Resource Damage Assessment

(NRDA) regulations drafted and adopted by the U.S. Department of the Interior.[12] Although the NRDAs are not mandatory and are currently undergoing revision by the Department of Interior as a result of a U.S. District Court decision,[13] they provide key definitions and outline the basic procedures employed by NOAA and other federal trustees pursuing natural resources damage claims.

REGULATORY FRAMEWORK FOR ASSESSMENT OF DAMAGES TO NATURAL RESOURCES

Under CERCLA Section 301, the President was directed to develop regulations for assessing damages under Section 107(f). This task was delegated to the U.S. Department of the Interior. The basic assessment portion of the regulations, which were to be promulgated by December, 1986, eventually were adopted on September 2, 1986. Consisting of Subparts A through F, these regulations incorporate both the CERCLA and the Clean Water Act (CWA) provisions allowing the designated trustees, including NOAA, to assess damages to natural resources resulting from either a discharge of oil or a release of a hazardous substance and to recover damages.

The intent of these regulations is to supplement the NCP provisions of 40 CFR Part 300 which deal with identification, investigation, study and response to oil discharges and hazardous substance releases focusing exclusively on the natural resource impacts of these discharges and releases. These regulations are not mandatory; however, application by federal or state trustees of the assessment process which they establish creates a rebuttable presumption the damages assessed by the trustee were determined in a reasonable manner and validly quantify the harm done. Although they are undergoing substantive revision by the Department of the Interior as the result of the District Court ruling in *Ohio v. U.S. Department of the Interior*, the regulatory framework, including key definitions, provides insight into how the government assesses damages under Section 107(f).

The regulations contemplate a planned and phased approach to the assessment process in evaluating damage claims. The intent is to be certain the procedures used in such assessments are appropriate, necessary and sufficient to assess the nature and extent of the damages. To achieve this intent, the assessment process is divided into preassessment, assessment and post assessment phases and the assessment phase is further divided into either simplified (Type A) or complex (Type B) assessments, both of which include Injury Determination, Quantification and Damage Determination phases. A brief overview of each of these phases and subphases in the context of a marine pollution episode illustrates how the process is intended to work.

The preassessment process typically begins when NOAA receives notice from the U.S. Coast Guard (USCG), EPA or other federal or state agency under CERCLA Section 104(b) (2) of potential damage to a marine resource resulting from an environmental release. In the case of previously unreported discharges of oil or releases of hazardous substances which have injured marine resources, NOAA has responsibility for reporting the matter to the federal or state authority designated in the NCP. Under appropriate emergency circumstances (e.g., where EPA and USCG do not respond), NOAA can take action on its own to prevent or reduce harm to the resources over which it acts as trustee. Limited sampling of potentially injured natural resources is also authorized. The general purpose of the preassessment process is to focus quickly on the natural resources impacted and document that:

- a release or discharge of oil or a hazardous substance has occurred,
- there is probability of injury to a natural resource,
- data sufficient to make an assessment is available or can be developed at a reasonable cost, and
- regular cleanup actions at the site, taken under CERCLA, will not sufficiently remedy the injury to the natural resource.

The process also calls for recognizing the extent to which PRPs exist and whether or not the damages are exduded from liability under CERCLA. In completing the preassessment activity, NOAA is to coordinate with the lead agency handling the response action.

The Assessment Phase with its simplified (Type A) and complex (Type B) subphases begins with the development of an assessment plan the content and development of which are specified in the regulations.[14] Part of this development process includes identification and involvement of PRPs. The trustee is directed to give the PRPs notice of and to invite their participation in the assessment process. For incidents involving coastal and marine environments the type of assessment selected depends on NOAA's evaluation of a specific range of factors including:

- The results of analysis pursuant to a specially developed technical document titled "Measuring Damages to Coastal and Marine Natural Resources: Concepts and Data Relevant to CERCLA Type A Damage Assessments" (NRDAM/CME Technical Document),
- The duration of the release/discharge,
- Whether the discharge/release resulted in closure of a beach, fishing or hunting area,
- Whether chemical dispersants were used, and
- The expected impact to any biological resource.

The simple assessment process for coastal and marine environments involves extensive use of a computer model identified and described in the NRDAM/CME Technical Document intended to minimize field research. The complex or Type B assessment is a more detailed process which substantially expands the discrete subphases of Injury Determination, Quantification and Damage Determination. The requirements, steps and contents of each subphase are spelled out in detail in Subpart E.[15] Both processes are designed to develop general information regarding the discharge/release and its impact and then to focus on environmental parameters (e.g. currents, tidal velocities, wind direction and speed, and ocean depth); results of cleanup action (which can provide a basis for determining residual contamination); and the impact of discharges or releases occurring outside the coastal/marine environment.

The injury determination segment of the assessment phase in a marine resources investigation focuses on physical fate and biological effects of the release or discharge using either submodels of the NRDAM/CME program in Type A assessments or the results of direct sampling and computer analytical data for Type B assessments. Contamination pathways for environmental receptors are identified and examined; confirmation of environmental exposure is either assumed (for Type A assessments) or documented based on site activity (Type B). Finally, injury determination is developed by the NRDAM/CME biological effects submodel in the Type A process or through comprehensive testing and sampling of surface water, geologic and biologic resources under the Type B process.

Of most direct concern to PRPs, the final step in the assessment process is Damage Determination. The Subpart F regulations basically identify a damage determination process utilizing a "restoration methodology" (employed where the natural resource can be restored to pre-release/discharge conditions) or a "use value" methodology (employed where a marketed or non-marketed resource has been destroyed or can not be restored to its pre-release/discharge condition). As written, Subpart F required the trustee to determine the value of the natural resources injured, lost or destroyed based on an evaluation of (1) "replacement/restoration" costs and (2) "diminution/loss of use" costs. In selecting between these mutually exclusive measures, the trustee is directed by current NRDA regulations to select the lesser of the restoration/replacement and the diminution/loss of use values unless restoration/replacement is not technically feasable.[16]

This "lesser of" requirement in the regulations governing natural resources assessments was among the provisions attacked by the plaintiffs in *Ohio v. Department of Interior* (cited above), and one which the District Court found contrary to Congressional intent. The ruling, which directed Interior to revamp much of its assessment regulations, is likely to result in a preference for assessing natural resources damage based on replacement/restoration costs instead of diminution/loss of use values, meaning damage assessments will be generally higher. Furthermore, in calculating what those restoration/replacement cost values are, the Court directed the trustee to look beyond market values and venture into more speculative areas such as calculating the "existence" value of a now destroyed natural resource.

The Damage Assessment Report, which is issued as part of the Post Assessment Phase in the regulatory process, serves the dual purpose of providing the PRPs with a written estimate of natural resources damages attributable to the discharge or release and setting up for the trustee (should litigation be necessary) a rebuttable presumption as to the basis for and the amount of damages recoverable. The trustee is authorized, but not required, to give the PRPs at least sixty (60) days to acknowledge and respond to the report (which is treated as a demand for payment) before initiating suit.

In re Acushnet River Case History

The proceedings known as *In re Acushnet River and New Bedford Harbor* (D.C. Mass 1990) involve a major CERCLA natural resources claim which illustrates the cost, complexity and uncertainties entailed in such litigation. At issue ultimately is the liability of a group of corporate defendants and their parents and predecessors for the costs of cleaning up PCB contamination from a heavily polluted river and harbor and for damages to natural resources. The latter damages, the state and federal government have measured by such wide ranging factors as reduction in local housing values, damage to lobster and fishing industry, presence of contaminants in wildlife, and diminution in use of beaches and waters.

In a series of rulings since 1987, the judge handling the case has ruled on matters ranging from the right to a jury trial in CERCLA claims, the liability of successor corporations, and the reach of federal service of process. The most recent rulings have focused on issues such as the meaning of the CERCLA Section 107(f)(1) provision regarding damages and hazardous substances releases wholly before December 11, 1980. These decisions, cited elsewhere in this paper, are well researched and entertainingly written by a judge who has had five years of handling the proceedings in which to become well-versed in the frustrations of construing CERCLA's "limited and inconclusive" legislative history, "poor drafting" and "incomprehensible nature."

The view for those observing *In re Acushnet* as it winds its way to trial is that the federal and state agencies prosecuting the case will use it as a model for future natural resource damage actions involving marine polution and ocean dumping. Given the government's range of real or imagined damage claims for damages ranging from harm to the fishing industry to damage to aesthetic values, the liability faced by the defendants is enormous. If the jury elects to ignore intervening mitigating factors such as the chronically poor local economy, pollution from other sources, and the historic decline in the local commercial fishing industry, the defendants in this case could well be tagged with the costs of compensating for the loss of an undefiled environmentally pure river and harbor estuary which never existed.

Limits on Liability and Potential Defenses

Among the differences between a CERCLA suit for recovery of response costs and an action for natural resources damages is ability in the latter action to avoid, in some instances, retroactive liability. As previously noted, Section 107(f) specifically provides that there can be no recovery where both the natural resource damages and the hazardous substance release which caused the damage occurred entirely prior to the date of CERCLA's enactment (December 11,1980). While it may be relatively easy to identify in certain catastrophic incidents when a release of a hazardous substance has occurred, establishing when damages occurred can be as difficult as calculating what those damages are. The court in *In re Acushnet River* *and New Bedford Harbor* held that damages do not occur to natural resources until expenses have been incurred by the government to remedy them.[17] The alternative view put forth by the PRPs, that damages occur when the natural resource sustains injury or destruction, was rejected by the court.

A second distinctive feature of natural resources damage claims is the relatively short statute of limitations for bringing suit. Cost recovery actions under CERCLA Section 107(b) must be brought within three years after a removal action is completed or within six years after a "remedial action" begins.[18] In neither instance does the date of discovery of a release trigger the limitations period. By contrast, natural resource damage claims must be made within three years of the later of (1) September 2, 1986, (the date the Department of Interior published its damage assessment regulations), or (2) the date of discovery of the damage and its causal connection to the release or discharge.[19] While some might argue as to when the Department of Interior's regulations became effective because of amendments to the Type A and B regulations, the September 2, 1986 date remains generally recognized at least by EPA and NOAA. Similarly, some argument can be made as to when the date of discovery commences, although the general view is that the time begins to run when the trustee becomes aware of the injury to the natural resource.

Potential defenses to liability for natural resource damage claims, where the circumstances are appropriate, may exist under the "federally permitted release" definition Section 101(10) of CERCLA or the language of Section 107(f) (1) regarding "irreversible and irretrievable commitment" of natural resources as part of the EIS approval process. The first part of the defense relates to lawful releases which occur pursuant to and consistent with the terms and conditions of permits issued under the Clean Air Act, the Clean Water Act, and other environmental statutes. The second part of the defense arises where the PRP has undergone an administrative review of a proposed project resulting in issuance of an Environmental Impact Statement (EIS) or negative declaration approving the project while recognizing there will be unmitigatable loss of or damage to certain natural resources as a result of the project. Of course this latter aspect of the defense looks only to prospective (post EIS) conduct and is strictly limited to natural resource damages recognized and accepted by the lead agency in the EIS process.

CONCLUSION

CERCLA's natural resource damage provisions have not generated substantial enforcement activity in the decade since they were adopted in 1980; however, their use in dealing with coastal and marine pollution claims is likely to increase as public concern over contamination of these resources heightens. The EXXON VALDEZ spill, the contamination of Boston Harbor, and the industrial and municipal sewage pollution problems associated with Santa Monica Bay in California, have all become major environmental concerns and, together with other environmental threats, will prompt the government to look more frequently to Section 107(f) claims. As substantial as the costs and expenses can be in remediating the effects of land-based releases of hazardous substances, the costs and expenses for addressing damages to the nation's marine resources may generate far larger amounts, particularly given the judicial mandate to calculate such damages based on the cost for restoration.

NOAA and the various federal and state agencies charged with protection of these marine resources have begun to move forward with the investigation and prosecution of these claims, utilizing complex modeling and assessment procedures to generate volumes of presumptively valid data about long term impacts to practical and aesthetic resources ranging from fishing grounds to the value of viewing a white, sandy beach. Under the circumstances, the fact that a relatively greater number of potential defenses may exist for PRPs facing liability for damage to these resources could be of slight comfort to those ensnared in the net of potential liability.

REFERENCES

1. 42 USC §§9601 et seq.

2. *U.S. vs Mirabile* 15 Env.L.R. 20994 (E.D.PA. 1985), *U.S. vs Maryland Bank & Trust Co.* 632 F.Supp. 573 (D. Md. 1986), *U.S. vs Fleet Factors Corp.* 901 F.2d 1550 (llth Cir. 1990), Cert. denied No. 90-504 (Jan. 14, 1991).

3. *In re Acushnet River and New Bedford Harbor Proceedings re Alleged PCB Pollution*, 712 F.Supp. 1010 (D. Mass. 1989).

4. *General Electric Company vs Litton Business Systems, Inc.* 4 IX.LR. 812, 32 ERC 1433 (8th Cir. 1990).

5. 42 USC §9607(f).

6. See e.g., Clean Water Act, 33 USC §§1251-1376; Safe Drinking Water Act, 42 USC §§300 et seq.; and Clean Air Act, 42 USC §§7401-7626.

7. 42 USC §§9606(a) and §9607(a).

8. The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) is set forth in 40 CFR Part 300 and establishes procedures for the identification, investigation, study and response to discharges of oil or releases of hazardous substances. The NCP is intended to implement the statutory mandates of both CERCLA and the Clean Water Act (33 USC §§1251-1376) in providing for assessment methodologies and remedy selection.

9. 42 USC §9607(f) (I).

10. 42 USC §9607(b) (3). The language here must be read in conjunction with the definition of "contractual relationship" in 42 USC §35(a) to develop what has come to be referred to as the "innocent landowner" defense which was established in the 1986 amendment to CERCLA. In effect, it creates a defense applicable to defendants who acquire a contaminated facility without knowledge or reason to know that hazardous substances were disposed of there, provided they can demonstrate having undertaken all appropriate inquiry into previous ownership and prior uses of the property consistent with "good commercial or customary practice."

While spawning a cottage industry of environmental assessments, the "innocent landowner" defense has done little to eliminate potential liability under CERCLA.

11. 40 CFR §300.600(b).

12. 43 CFR §§11.10-11.93.

13. *Ohio vs U.S. Department of Interior* et al. 88 F.2d 432 (D.C. Cir. 1989). The action involved challenges by the States of Ohio, Colorado, New York and Massachusetts, as well as a chemical industry trade association, a manufacturer and a utility seeking review of the Department's regulations governing natural resource damage claims. In its decision, the Court held that regulations limiting damages recoverable by government trustees or natural resources damages to the lesser of restoration/replacement costs or lost use value was contrary to Congressional intent and remanded the case to the Department for redrafting of its regulations so as to be more consistent with the statutory intent. As of this date, the Department has not come forth with a revised regulatory scheme.

14. 43 CFR §§11.30-11.35.

15. 43 CFR §§11.90-11.93.

16. 43 CFR §1I.35(b)(2)(3).

17. *In re Acushnet River and New Bedford Harbor Proceedings re Alleged PCB Pollution* 716 F.Supp. 676 (D. Mass 1989).

IS. 42 USC §9613(g) (2).

19. 42 USC §107(f)(I).

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How to Resolve Coastal Multi-Use Land Conflicts: Approach and Examples

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ABSTRACT

This paper describes ways to resolve coastal land use disputes not amenable to regulatory processes or high-cost land purchase alternatives. Regulation of coastal development is a necessary but insufficient part of an effective coastal resource management system. Regulation is faced not only with increasing pressures of population growth and development and confrontations between private property and public rights; it must also address competition among coastal resource goals, often inherent in coastal policies. How can we resolve conflicts between habitat protection, natural resource exploitation, public recreation, tourism, and farming? How will we retain local jobs, community character, and revenue generation while ensuring that the resources that provide a region's beauty and sustenance are not destroyed in the process?

Drawing upon the experience of the California State Coastal Conservancy,[1] several examples of non-regulatory approaches will be described. These coastal projects involve multiple uses, diverse interests, and often contentious situations. Their relationships with coastal and bay regulatory frameworks will also be described.

INTRODUCTION: COASTAL CONSERVANCY ORIGIN AND PURPOSES

California's coastal resource management program began with the passage of a ballot initiative in 1972. This initiative, Proposition 20, was placed on the ballot by

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concerned citizens after several unsuccessful attempts were made to pass coastal legislation. It established the California Coastal Commission with temporary but sweeping regulatory powers over all coastal development while it prepared a coastal plan. These powers were exercised in a coastal zone stretching from Oregon to Mexico, and extending inland 1,000 yards. (This was subsequently amended by legislation, narrowing in many urban areas and expanding as much as five miles inland in areas like Big Sur and the Santa Monica Mountains.) The Commission's administration between 1972 and 1975 of the most far-reaching development controls in the nation showed that there were still problems that were not being addressed by the regulatory framework.[2]

Regulation could not take affirmative action; it could only respond to issues brought to it through the permit process. It might prevent further filling of wetlands, for example, but it could not get a degraded marsh restored to biological health. It could require provision for public access to the shore, but it could not actually build and open up the accessway.[3] Its policies concerning protection of different resources sometimes conflicted, and were not easily reconcilable in many cases. Lacking acquisition power or other authority, it could either permit many pre-coastal initiative development plans or face possible legal action for prohibiting it. So the Commission's Coastal Plan of 1975 recommended that a new, nonregulatory body be established to address these issues.

The State Coastal Conservancy was created by the California Legislature in 1976, the same year the Coastal Act was passed, to make the Commission permanent and require local governments to prepare coastal plans. The Conservancy was directed to protect, restore and enhance coastal resources by implementing several programs. These programs included provision of public access, agricultural land conservation, restoration of improperly planned rural development sites, protection and enhancement of wetland and other natural habitats, reservation of environmentally sensitive lands for future public use, acceptance of donations and dedications of land, and, later, restoration of urban waterfronts.[4] In fact, the underlying reason for establishing the Conservancy was that another means was needed to resolve coastal land use conflicts that the state's coastal regulatory framework could not adequately handle; to facilitate environmentally sound coastal development; to ameliorate the sometimes severe effects of necessary regulation; to demonstrate innovative methods of conserving coastal resources; and to assist local governments in implementing their local coastal plans.

The Conservancy's jurisdiction initially was co-terminus with that of the Commission. In 1980, the Conservancy's authority was extended into San Francisco Bay as well. It was further expanded to enable it to deal with problems outside the coastal zone that were causing negative impacts on resources within the zone.

In order to operate, the Conservancy was provided with $10 million from a bond act passed by the voters in 1976. These funds have been supplemented several times since by other bond acts. Small amounts from other special funds such as tidelands revenue and environmental license plate funds have also been used for specific projects.

Since its inception, the Conservancy has approved over 450 coastal projects, costing over $161 million. The following case examples are typical of situations for which Conservancy assistance is needed, and illustrate how its methods complement the Commission's regulatory mechanism. (In San Francisco Bay, the Conservancy has a similar relationship with the Bay Conservation and Development Commission [BCDC], which regulates shoreline development around the Bay.)

PROJECT CASE EXAMPLES

Five Conservancy projects are described here. Their settings vary from urban beachfront to bay marsh and rangelands, from forested wilderness to rapidly developing lands on the urban fringe. Issues encountered include development rights and local financial needs vs. public access, job displacement vs. habitat protection, conflicts among public uses and between them and range management practices, and cumulative impacts on habitat and open space. In each case, the Conservancy approached the situation differently, and devised different methods for arriving at solutions that the concerned parties could agree upon.

Oceanside Strand Waterfront

Oceanside, a city of around 85,000 people located on San Diego County's northern coast, was a declining beach resort whose badly eroding beach symbolized its economic decline, when it contacted the fledgling Coastal Conservancy for help in 1977.[5] The city's financial woes were aggravated by the fact that it was not quite poor enough to qualify for major federal urban aid, yet not affluent enough to manage on its own. Political fragmentation seemingly prevented consensus on development and conservation goals for its beachfront area, known as the Strand. The city favored private development to generate badly needed revenue, and at the same time wanted to restore and improve the Strand's public access and recreational facilities, especially its beach; developers naturally wanted prime waterfront sites; residential property owners were concerned about loss of ambience and views; poorer segments of the population wanted shoreline development to serve them as well; general concern existed regarding what to do about the marines from nearby Camp Pendleton and the businesses serving them in the city; and the Coastal Commission, representing the state's interests, required the city's Local Coastal Program to include enough "offsetting public benefits" to balance whatever private development might be allowed.

The city and the Commission had reached an impasse when Oceanside officials initially approached the Conservancy for financial help in acquiring some beachfront land for a park. Unable to provide the full amount of money the city had asked for, and aware of the fragmented local political situation, the Conservancy suggested instead that it and the city co-sponsor a public design workshop process to devise a plan for the entire one and one-quarter mile Strand. This plan would identify solutions to the various issues, specific redevelopment projects to be done and their priorities, and sources of project financing. All this would be agreed upon by the city, the Conservancy, and the Coastal Commission.

At first, the city did not favor the workshop idea. A private developer was on contract to prepare a redevelopment plan for an area that included the Strand. City officials also had already handpicked citizens advisory committees for both coastal and redevelopment plans. An open workshop process appeared fraught with problems and dangers: duplication of effort, waste of time and money, opportunities for contentious citizen agitation, and more work for city staff. While discussions between Oceanside and the Conservancy continued, winter storms severely damaged the municipal recreational pier. The city's aid request expanded to include it and other deteriorated public recreational facilities. These could readily be included in the Strand plan, said the Conservancy, as devised by the community workshop process. The proposal was sweetened by the Conservancy's offer to fund the workshop process and, at least partially, implementation of any projects that emerged. After about a year and a half, the city assented to the workshop process, after firm assurances that they would not lose control of the process, and would jointly agree on the work program with the Conservancy.

A waterfront restoration plan and program were prepared by participating citizens, assisted by city and Conservancy staff and economic, design, and workshop consultants, through five workshops. Participants walked the Strand area, formulated design guidelines, helped select the design consulting team through an unusual two-day public competition, and then evolved the program. Public improvements identified included the damaged pier, a community center and amphitheater, acquisition of several acres of private land for new waterfront parks, new accessways down to the Strand, and other improvements.[6] These were the "offsetting public benefits" that the Commission wanted to see in the city's Local Coastal Program.

During the workshop process, a new conflict arose. Irate citizens discovered during a public redevelopment hearing that a private developer, under contract to the local redevelopment agency, had prepared a draft master plan for the entire downtown, including the Strand, without any public input. The city quickly arranged for developer's representatives to meet with citizen workshop participants, city and Conservancy staff, to resolve the half dozen differences between the workshop and developer plans. The first five issues were resolved in short order; the sixth, concerning site preferences for the park and a condominium development, was worked out by a mutually acceptable solution. The final workshop plan, which included the settlement with the developer, was endorsed by workshop participants, the city council, the Conservancy, and the Coastal Commission. It was then incorporated into the Oceanside Local Coastal Program. Over the next seven years, the city, assisted by a citizens' task force formed from workshop participants, implemented the plan. Funds came from city, private sector, Conservancy, and other state and federal sources. Several of these sources were identified and arranged for by the Conservancy, in addition to its own financial involvement.

Sinkyone Wilderness

Far to the north of Oceanside lies a part of the southern Oregon and northern California coast once covered with giant coast redwood trees, which grow nowhere else on earth.[7] Now only about five percent remain, the rest having been logged for lumber. This remnant has become the subject of fierce controversy; and among the most intense was that over the 10,000 acre Sinkyone Wilderness, located in northwest Mendocino County between the Pacific Ocean and the first coastal mountain ridge.

The conflict was whether the remaining old growth redwoods, some more than a thousand years old and comprising one of the most complex and unique ecosystems in the world, should continue to be logged. The owner, the huge Georgia Pacific Lumber Company, wanted to continue logging the trees, which provided superb building material and hence further profits. The loggers and woodworkers in the company's nearby mill wanted to maintain their jobs. Along with officials who saw the timber yield tax on the old growth as a badly needed source of revenue for the financially beleaguered county, they also wanted to see logging continue.

Opposing them were a variety of interests who were united in their intense desire to see logging cease in the Sinkyone. To the survivors of the indigenous inhabitants of the region, the redwoods of the Sinkyone and in particular, the Sally Bell Grove, were "blood relatives," a sacred treasure.[8] Local environmentalists, including the Environmental Protection Information Center (EPIC) and the Sierra Club, acknowledged this view, and, in addition, marshalled strong ecological arguments for protecting what was left of the once vast forest region.

Efforts to protect at least part of the Sinkyone had continued since the 1960s. The state Department of Parks and Recreation had purchased 3,500 acres early in the 1970s which became the Sinkyone Wilderness State Park. Not included in this purchase, however, were the Georgia Pacific lands to the south. No public access was provided through it and the Sierra Club continued its efforts to get a trail corridor established. The company finally offered to lease a coastal trail alignment in the early 1980s, but was unwilling to sell anything less than the entire 7,100 acre holding as a whole.

Meanwhile, logging continued, and in 1983 opponents filed suit against Georgia Pacific and eventually, in 1985, obtained a temporary injunction to halt logging until the courts had ruled on the suit. The interim had seen confrontations of anti-logging protesters and loggers and sheriff's deputies in the forests, and an increasingly heated and tense atmosphere.

The controversy had raged for well over a decade when, in March 1986, informal discussions took place between the Conservancy and the local county supervisor most directly involved in the Sinkyone affair. These talks covered a range of concerns for which the supervisor sought Conservancy assistance, although the Sinkyone was not high on the list as continued logging was the county preference. Nonetheless, Conservancy staff was asked to speak before the full Board of Supervisors about what assistance the agency might be able to give the county. This done, the supervisors decided to ask the Conservancy to convene and "coordinate" a committee of concerned parties to the Sinkyone controversy to review the issues and see if something positive could be done. At the same time, however, the board voted against further land acquisition in the Sinkyone "at this time," sustaining their current position but leaving the door open for reconsideration pending the outcome of the committee's deliberations.

Conservancy staff agreed to undertake the task, with the clear understanding that the goal was to reach consensus on a solution that included resource conservation and was consistent with state laws and policies. This was acknowledged all around, and the committee was formed. It included representatives of the native American residents, EPIC, the Sierra Club, the Departments of Forestry and Parks and Recreation, Mendocino County, Georgia Pacific, the woodworkers union, the state senator and assemblyman who represented the area; and, of course, the Coastal Conservancy.

The Coastal Commission did not play a major role in this situation, as the logging company was not applying for a coastal permit and the Sinkyone issue was not a subject of concern in the county's Local Coastal Program, which by this time had already been approved by both Mendocino County and the Commission and allowed logging.

In view of the long and intense history of conflict, Conservancy staff decided that the most useful approach initially would be to meet separately with each of the committee members, to elicit their concerns, desires, and proposals in the least threatening circumstances. While this process was going on, the Conservancy consulted with forestry experts to obtain accurate information on the subject property's timber resources, their worth, and the implications for further employment and revenue. This was most important because of strong but often unsupported opinions held by some of the participants in the controversy.

By mid-summer, a draft proposal had been prepared by Conservancy staff for review by the committee. This proposal called for somewhat less than half of the property, including all the remaining old growth, to be permanently protected; the balance, which contained no old growth trees, would be suitably restored from the ravages of previous logging, and made available for multiple uses including logging. As the committee prepared to deal with this idea, the non-profit Trust for Public Land suddenly announced it had obtained an option to purchase the 7,100 acre Sinkyone property from the logging company.

The Trust had previously worked with the Conservancy on another large project, and had quietly offered its assistance to buy the Sinkyone land. The Conservancy declined to be associated directly with the Trust at this point because this might be perceived as compromising its role with the committee; but did not stand in the way of the Trust's contacting the logging company on its own.

With the non-profit's announcement, the tentatively emerging consensus began to unravel. The logging interests envisioned the loss of the area to timber harvesting completely. Yet, while the environmental and native American groups were enthusiastic about the possible purchase, they rapidly became uneasy because the Trust had only about half the purchase money lined up (a combination of previously appropriated stated funds with the State Parks Department and other money from the non-profit Save the Redwoods League). The Trust might not buy the property, leaving open the possibility of another company attempt to log it. In addition, the company's sale offer was good only through the end of the calendar year, so that it could get beneficial tax treatment on the sale. Conservancy funds were available, but only on condition that the entire committee reached consensus that it should be so used, and that the county board concurred.

Committee members saw that it was time to act in concert, and the committee met as a whole to review the Conservancy's preliminary proposal and craft a final alternative on which they could agree. This was quickly done, with the solution roughly following the outlines of the original proposal. A final funding package was put together with Conservancy money and additional funds from the League, and in late December the Conservancy approved the Sinkyone plan and acquisition funding. The county board of supervisors followed with its approval, with a vote that was the reverse of its decision less than a year earlier; and, under a cooperative agreement with the Conservancy, the Trust acquired the property.

Three thousand of the Sinkyone acres, including the Sally Bell Grove and other old growth, have become an extension of the state park. The Conservancy continues to work on a management and disposition plan for the remaining 4,100 acres, including stream and habitat restoration, provision of public hiking trails, and protection of native American and archaeological sites. Concern remains on the part of the native Americans, however, that most of this area might still be available in the long term for resumed logging, albeit under environmentally enlightened "best management practices" for sustained yield. They would prefer a "tribal park." So work continues on non-logging alternatives, possibly including off-site logging, that would be mutually acceptable.

Rush Ranch

A few miles above where the Sacramento River empties into the San Francisco Estuary lies the Suisun Marsh, the largest remaining tidal marsh in the country. On its northeastern shore within sight of the rapidly growing county seat of Fairfield is the Rush Ranch, 1,900 acres of rolling grazing land and wetland with spectacular views of the entire marsh and surrounding area.

The Rush Ranch controversy was not about land acquisition, but about land use. Using its special powers to take rapid action, the Conservancy responded to an urgent request in early 1988 from a newly formed land trust, the Solano County Agricultural and Open Space Foundation, to help save the ranch before a foreclosure sale put it into the hands of potential developers. Within less than five months the Foundation, with Conservancy funds, was able to buy the ranch. The joint intention was to formulate a management plan to improve the wetland habitat of the marsh acreage, modify the current cattle grazing practices which were damaging the marsh and over-grazing the grassland, and to provide new public access trails and educational and viewing facilities. Here was where the problems arose.

Shortly before the Conservancy board took action on the acquisition funding, local hunting interests voiced their loud opposition to the purchase unless hunting of birds and other wildlife were to be permitted on the ranchlands. Duck hunting was permitted in the adjacent state-owned Suisun Marsh preserve, the private landowner had allowed hunters on the ranch property in the past, so the practice should be allowed to continue.

Here was a controversy that is becoming ever more common as human settlement spreads over our remaining open lands. At issue was not only the question of wildlife management, or the more emotional element of whether wild creatures should be killed at all, but also safety considerations arising from the intended public recreational use of the site, which was just beyond the outskirts of the fastest growing city in the region.

In a very rare occurrence for the Conservancy, the hunters' opposition to the Conservancy's assistance in the acquisition was voiced at the agency's board meeting on the project. In authorizing the purchase of Rush Ranch, the Conservancy acknowledged the hunters' concerns and determined to consider them during the preparation of the management plan. To make sure that all concerned interests were heard, a committee was formed by Conservancy staff to help formulate a mutually agreeable plan. The committee was comprised of hunting interests, the county, the local resource conservation district, the state Department of Fish and Game, the San Francisco Bay Conservation and Development Commission, which had to approve the plan, the non-profit organization, and the Conservancy.

In contrast to the Sinkyone experience, this committee met as a group from the outset. The Conservancy and Foundation technical consultants provided detailed information and recommendations regarding all aspects of the proposed land uses, which was reviewed by the committee. To deal with the hunting question, agreement was eventually reached on several points. Duck breeding area was to be expanded within the wetland acreage of the ranch, although actual hunting would not be permitted. In addition, an experimental vegetation program would be undertaken to see if the type of plant cover needed by pheasant and other land creatures which were potential hunting targets could be satisfactorily grown on site. Consultant studies had indicated that the site currently was not hospitable to such plant species, but the attempt would be made to confirm this finding.

During the course of the committee and consultant work, another issue surfaced that threatened to dissolve the fragile bonds of agreement that had grown during the planning thus far. This one concerned the extent of grazing to be permitted under the new management regime. Specifically, how close to the marsh would cattle be allowed to graze? Cattle interests wanted to retain as much area as possible. Wetland managers wanted to withdraw the grazing activities back from the marsh to a safe and secure distance. After much discussion among the committee members and with the consultants, cattle interests acquiesced in the decision to withdraw grazing to the other side of the access road into the Rush Ranch. A deal had thus been struck, and the management plan was approved by all the relevant organizations in 1989.

BCDC was particularly concerned with both protecting the marsh and uplands and their wildlife inhabitants, and with making the site available for public use. The Commission thus had no problems with the management plan.

Along with its adoption of the site management plan, the Conservancy also approved funding for the Foundation to carry out the site improvements, including provision of the public access facilities.

Huntington Beach Wetlands

Only within the past twenty-five years have wetlands become a conservation priority. Considered by settlers, farmers, and developers as insect-infested swamps or, at best, degraded building sites, wetlands have been diked, drained, filled, and converted to farmlands, housing tracts, and shopping malls. More recently recognized as biologically and economically valuable, and as water quality enhancers and flood control buffers, wetlands have become the focus of environmental protection efforts as their alarming rate of loss has been noticed, even at the national level, for the first time.[9]

In California, fully ninety percent of coastal wetlands have vanished, to be replaced by some of the most coveted development in the country. The formerly vast coastal salt marshes of what is now Orange County in southern California have been reduced to a few scattered remnants. One of these, a 147 acre wetland area in the city of Huntington Beach, became the subject for one of the Coastal Conservancy's more complex projects.[10]

This degraded marsh lay next to one of the state's most heavily used beaches and a site for world surfing championships. At first, the city saw the development potential of this wetland and sought to replace it with houses and shops. To its surprise, its 1979 Local Coastal Program land use plan for the marsh was rejected by the conservation-minded Coastal Commission, for whom protection of the coast's few remaining wetlands was a top priority. The city then sought financial help from the Conservancy to do a waterfront development plan for the area. This approach did not appear to have much promise to the Conservancy, but it eventually agreed to assist the city in resolving its conflict with the Coastal Commission.

The marsh had five owners, the state Department of Transportation (Caltrans), the County Flood Control District, Southern California Edison, a private development company, and a private individual. None of these owners shared the Commission's view of the importance of the endangered shorebird species that inhabited the marsh, or of the marsh itself. The city was concerned about possible lawsuits resulting from zoning the area as wetland, even though the state Department of Fish and Game had so designated it.

After preliminary exploration, the Conservancy realized that wetland protection and completion of the city's coastal land use plan could only be achieved if it did not prevent the economic return from their property expected by the landowners. Eventually, in February 1985, Conservancy staff proposed a potential solution to the city. This included preserving and improving most of the wetland, using part of it as a mitigation site for highway widening and flood control channel improvements projects of the state and county, trading properties to settle outstanding lawsuits against the state arising from prior land purchases, exploring possible acquisition from the private landowners, and assisting the city in resolving its planning issues.

The city's initial reaction was discouraging, but local citizens began to voice their concerns for saving the marsh, and the Conservancy agreed to review the Fish and Game site determination and meet with the landowners. After much debate, the city council agreed to the approach and work proceeded. Having confirmed the Fish and Game Department's findings regarding the validity of the wetland determination, the key was to identify economic alternatives for the landowners. these included acquisition, development adjacent to the marsh, and transfer of development to other sites.

A major concern centered on mitigation needs of the Department of Transportation and the Flood Control agency, both of whom had proposed large public works projects that would damage the marsh. These agencies were not sure how to compensate for the losses their projects would generate. The Conservancy suggested that Caltrans sell its property to the Conservancy, and that Caltrans and the Flood Control agency pay for a wetland enhancement project to be carried out by a newly formed land trust, the Huntington Beach Wetlands Conservancy, with Coastal Conservancy assistance and the cooperation of the two public works agencies. The agencies' payments would cover the necessary mitigation costs of their own highway and flood channel projects. The agencies agreed without prompting to this arrangement.

Southern California Edison was ultimately cooperative toward a land use plan that included protection of the wetland. The situation with the remaining private landowners was less positive, however. For the private development company, the Conservancy proposed an alternative which included development on a seven acre non-wetland parcel in the form of a 180-room hotel, based on a detailed economic analysis. Unfortunately, it was not favorably received, nor were overtures to the other private landowner. The issue was the great gap in expectations of value which, for the landowners, ranged from $300,000 to over $1 million per acre, while the Conservancy's estimates, based on previous appraisals of other southern California wetlands, were down around $6,000 to $10,000 per acre.

In the end, the Conservancy could report to the city council that three of the landowners would probably be cooperative toward a new land use plan, which should now be prepared. The city proceeded to prepare a new draft, but controversy resumed as pro- and anti-development advocates clashed at council review hearings in early 1986. Finally, in June 1986, the Huntington Beach City Council voted to permanently protect the wetland, thereby enabling it to submit a coastal plan to the Commission that would be accepted.

Since then, the Conservancy and the local land trust have acquired the Caltrans property and completed the repair and enhancement of the marsh on twenty-three acres by restoring tidal action, planting of salt marsh vegetation, providing public access, and improving flood protection. These actions, which include the mitigation work, enable the long-delayed Caltrans and flood control projects to proceed.

Regrettably, the recent Huntington Beach oil spill caused minor damage to the newly improved wetland. Yet more repairs will be done, this time paid for by those responsible for the oil spill once a settlement is reached by the state. And, with the approval of the city's coastal land use plan, the opportunity still remains for an eventual accommodation with the two private landowners, which would lead to restoration of the entire marsh.

Huichica Creek Watershed

The last project example illustrates how a land use conflict directly involving private and public interests can be resolved in an actively cooperative manner from the outset. In the past decade, this scenic 4,500 acre watershed in southern Napa County has experienced rapid conversion from rangelands and dairy farms to intensive vineyard cultivation.[11] The watershed drains into Huichica Creek, which is an essential source of freshwater for the downstream Napa Marshes on the shore of San Pablo Bay. These marshes are among the few remaining waterfowl nesting areas in the entire San Francisco Bay region. The creek also provides instream habitat for freshwater fishes and the endangered California freshwater shrimp. The rapid spread of vineyard development has led to increased diversion of water out of the creek for irrigation. This practice, as well as pesticide runoff and hillside erosion, have had ill effects on the flow of fresh water to the marshes, which in turn has affected ducklings of nesting waterfowl and has threatened the shrimp and other species.

A local voluntary, non-regulatory agency concerned with improving agricultural productivity in environmentally sensitive ways, the Napa Resource Conservation District (RCD), recognized the need to counteract the impacts of the rapid vineyard conversions on the watershed before a political crisis occurred. The RCD formed a stewardship group consisting of representatives from the U.S. Soil Conservation Service, the Fish and Wildlife Service, the state Departments of Fish and Game and Agriculture, the Agricultural Extension Service, and others to consider how to address the problem. Assistance from the non-profit Napa Land Trust was also forthcoming. But additional technical and financial help was needed to bring together the necessary resources to actually address the situation.

The RCD contacted the Coastal Conservancy in 1990 for help in planning, financing, and implementing measures to solve the problems facing the vineyard operators, in the hope of averting the aforementioned crisis. The RCD and the growers initially focused on the water quality problems generated by chemical pest control measures. From the Conservancy's point of view, the health of the watershed, and ultimately the marshes as well, required overall enhancement which included but was not limited to resolving the pesticide issue. Working with the RCD, its stewardship group, and the growers in the area, the Conservancy devised an approach which called for a watershed enhancement plan to be prepared.

This plan, whose cost will be covered by the Conservancy, will focus on problems of water quantity and quality, soil erosion, and improvements to and revegetation of the creek channel and watershed lands. New cultivation methods will also be tested over a two-year period, including low water irrigation trials on vineyard area set aside for the purpose by one of the cooperating growers; tests of integrated pest management strategies on other area provided by another grower, which would include planting vegetation which supports natural insect predators, and will also test the effectiveness of vegetative diversity and cover crops on insect pest control; and, finally, a test of different cover crops to control soil erosion into the creek on fields set aside by a third grower. Implementation of the plan's various measures will generate information to be used to devise immediate protection and enhancement methods for the Huichica Creek and its natural resources.

While this approach appeared promising to the participants, they were aware that growers view commitments of money and resources to uncertain outcomes with caution, unless such demonstrations prove both effective and economic. This is especially true of viticulturists, who undertake very capital-intensive land preparation before they even start cultivation. Little or no long-term research results exist as to how environmentally sensitive cultivation methods work under varying climatic and economic cycles and what their economic benefits actually are.[12] As the issues were being discussed, a watershed land-owner indicated his desire to sell a nineteen acre parcel. To the RCD and the Conservancy, this provided a fortunate opportunity for demonstrating the new methods on an economically viable basis. The Conservancy then got financial support from the state Wildlife Conservation Board, which manages the Napa Marshes and thus has a direct stake in the creek's improvement; and, adding its own funds to the pot, enabled the RCD to buy the parcel. The overall project will therefore include the only long-term (five years) demonstration vineyard of commercial size which will yield information to growers throughout northern California otherwise unavailable.

DISCUSSION

The five project examples outlined above collectively address a wide range of resource situations and issues. On the Oceanside Strand, the concern was with preserving and improving public access and use of the waterfront by a variety of users, while enabling compatible development to proceed which would yield needed revenue to the city. The Sinkyone controversy embodied a classic confrontation between natural resource protection — the old growth redwood forest and its unique ecosystem — and the retention of logging jobs and associated revenue to the financially depressed rural county. Also underlying the conflict was a clash between ways of life and beliefs: those associated with the timber industry who viewed the cutting of trees for lumber as a legitimate pursuit, and those who considered the forest and its ancient trees as sacred ground and an ecological treasure to be revered and protected. The Rush Ranch problem reflected increasingly common competition over space, as urban development spreads over open lands and reduces the available area for fish and wildlife habitat, agriculture, and rural recreational activities like hunting. At Huntington Beach, another common conflict, that between urban development and wetland protection, exemplified the growing recognition nationwide of the importance of wetlands in our environmental consciousness in conflict with the old view that wetlands are of little or no use other than as development sites. In the Huichica Creek Watershed, a somewhat different land use dilemma exists, with vineyards replacing urban growth as the source of the problem for the wetland and watershed habitats.

To successfully respond to these diverse situations, the Coastal Conservancy had to be flexible in its approach, willing to try new or different methods, while maintaining a common basis, or principles, for its assistance. Conflict resolution is often viewed in terms of reaching a compromise, or "balancing" of goals, in which something is lost but something is gained as well. In contrast, the Conservancy has tended to view land use conflict resolution as an accommodation of diverse interests, in which resource goals are basically achieved, but not necessarily in the ways they may have been initially anticipated.[13]

This process of accommodation typically involves several things. First, all relevant interests had to be brought into the search for a mutually acceptable solution, and their real interests articulated and made part of that solution. Where this was fully possible, as in the Oceanside, Rush Ranch, and Huichica Creek cases, successful action has occurred. Further activity will be needed in the Sinkyone and in Huntington Beach to completely resolve these situations.

The Oceanside and Huntington Beach cases directly involved disputes between local government and the Coastal Commission that impeded the completion of the Local Coastal Programs for these cities. The Commission, in its role as administrator of the Coastal Act, wanted to make sure that development did not adversely affect two of its top priority concerns, protection of public access (in Oceanside) and wetlands (in Huntington Beach). In its non-regulatory role, the Conservancy had to find alternatives that would achieve these goals while enabling development to occur.

In Oceanside, the Conservancy made early use of public community design workshops to involve all interests, including the Commission, in formulating a solution. This took the form of a restoration plan for the entire Strand that included several specific projects, ultimately funded wholly or in part by the Conservancy, that assured adequate public access to, and use of, the shore. This approach was especially effective here because the city at that time was politically fragmented; the workshops gave the various factions an opportunity to be heard and to directly participate in crafting the solution.

The Huntington Beach dilemma was different. Here, the Conservancy needed to address the specific concerns of the several landowners in a more polarized situation. For the public agencies, a means was needed of providing mitigation for the wetland losses resulting from their road widening and flood control projects. The Conservancy ultimately acquired land from Caltrans, and drafted and brought about the signing of an eight party mitigation agreement, which included the Commission, to create the framework for implementation of both the public works projects and the restoration of the marsh. The latter was done by the newly formed nonprofit Huntington Beach Wetlands Conservancy, which was funded by the Coastal Conservancy. For at least one of the private landowners, development alternatives were proposed which would have provided a reasonable return on investment, but these were not acceptable to the landowner.

The Conservancy used other techniques besides structured design workshops for involving the interests to land use disputes. In its Sinkyone and Rush Ranch projects, committees were formed to reach agreement on project alternatives, but there were important differences between the two. While a severe polarity existed at the Sinkyone over whether or not to continue cutting trees, the numerous interests represented on the committee were at variance on a number of subsidiary issues as well. In this highly charged atmosphere, the Conservancy thought it best not to convene the committee as a whole until much better information was available regarding the nature and value of the land and its timber, and the short- and long-term employment prospects were clearer; the particular concerns and desires of each of the committee representatives were better understood in a less threatening context than a formal meeting; and until some tentative alternatives could be drawn up to stimulate more informed and focused discussion. Only after what appeared to the Conservancy to be a realistic accommodation of all interests was formulated, was the committee of the whole convened.

In contrast, passions over the future of Rush Ranch were cooled somewhat by the Conservancy's willingness, as a condition of its approval to proceed with the project, to form a committee of all concerned interests which would actively participate from the outset in preparing the management plan for the ranch. This included developing the work program for the consultants, who were to study the site and make recommendations for wetland enhancement, improved range management practices, provision of public access and interpretive facilities, and what to do about the hunting issue based on their study findings; as well as reaching consensus on the provisions of the management plan. Of importance was the agreement that all parties had to assent to the management plan before it would be implemented.

At Huichica Creek the land use conflict had not yet broken out into open antagonism between growers and those concerned about the future of the creek and the downstream marshes. The formation of the stewardship group by the resource conservation district was a positive step toward a solution to the complex problem that appears to have staved off a crisis. The Conservancy's role in broadening the group's scope of concern to include overall watershed enhancement issues, in supporting the idea of testing and demonstrating improved methods of cultivation and land management, and in arranging for needed funding has added the missing ingredients to this real public-private partnership.

The accommodation process also involves getting to the heart of the technical issues, and then formulating alternative approaches to resolving the issues. In all five cases, Conservancy staff and consultants, and other technical resource people, developed specific information that was essential to clarifying the substance of the disputes. This task was most evident in the Sinkyone, Oceanside, and Rush Ranch situations, but in the others as well. Project alternatives were proposed in all of the projects, with preferred ones eventually being agreed upon by project participants in most cases. The Oceanside workshops, the Sinkyone discussions, the Rush Ranch committee deliberations, the proposals for Huichica Creek Watershed, and the mitigation and private development alternatives were all prepared in this context.

This process of formulating project alternatives has frequently led to the demonstration of innovative methods and techniques for resource conservation. The Huichica Creek project itself is conceived as a demonstration of more environmentally sensitive cultivation methods. The use by the Conservancy of community design workshops to resolve multi-party disputes in urban situations, as at Oceanside, was something of an innovation on the California coast, although the technique had been used successfully elsewhere. Its ability to resolve such conflicts through its projects that the regulatory framework administered by the Commission could not handle was, of course, one of the chief reasons for the agency's establishment. The Rush Ranch management plan and its implementation may also be viewed as a demonstration of effective multiple use planning for competing resource uses which are increasingly at odds with one another. In this case no conflict existed directly between the Bay commission and any of the interests involved in the Rush Ranch project. The management plan solution did have to be approved by BCDC, however, and BCDC was a member of the committee working on the plan. Finally, the Huntington Beach wetlands mitigation agreement also demonstrates how complex mitigation arrangements can be brought about in a positive manner, in situations where over-riding considerations necessitate some loss of wetland habitat.

Consideration of economic factors was a major part of the solutions for all five projects, and is a necessary component of the accommodation approach to conflict resolution. It is key to obtaining the willing participation of those interests who otherwise would be less inclined to cooperate. Financial benefits to local government, such as the city of Oceanside and Mendocino County had to be considered, as they were for private landowners or developers in the projects. Even in the case of Rush Ranch, which ended up being owned entirely by the nonprofit, operations and maintenance costs of the ranch had to be factored into the plan, and the extent of continued cattle grazing on site to be permitted influenced these calculations.

Conservancy funds were used in all projects, for purposes which included planning, technical studies, land acquisition, and site restoration and development. While all of the projects' success depended on the availability of these funds, and although the basic issues in each case had economic aspects, the problems were not primarily those of funding land purchases. Even had enough money been available, acquiring land on the Strand for public use would not have solved either the city's revenue problem or its dilemma with the Commission. Funds to buy the Sinkyone had been appropriated previously by the Legislature, but had been removed from the budget by the governor because of the county's opposition at the time, based on their concerns with revenue and job retention. The Conservancy and the Solano Foundation were able to quickly acquire the Rush Ranch, but that purchase was not opposed by anyone; the use of the ranch was at issue. At Huichica Creek, the question of acquiring all of the vineyards causing the problems in the watershed was never a question at all. Even at Huntington Beach, the wide disparity of opinion between the Conservancy and the owners as to the fair market value of the privately held wetland property precluded the purchase of these lands; and the mitigation problems of the public agencies had to be solved in any event.

Lastly, a firm commitment is needed, especially on the part of the government agency concerned, in terms of time, effort, and resources to bring about the resolution of such land use disputes. This commitment was demonstrated in the Conservancy's case in these projects, some of which, like Oceanside, continued (through actual implementation of the project elements in the final Strand plan) for seven years. All of the others have involved at least a year of preparatory work, and sometimes over two years (the Huntington Beach case), to achieve even a partial resolution of issues before implementation.

To conclude, the five examples of coastal projects summarized herein describe ways of resolving land use conflicts in a non-regulatory manner, and approaches to positive action for resource conservation in situations where the regulatory mechanism cannot play these roles. The State Coastal Conservancy's experience over the past dozen years with hundreds of projects suggests that the Conservancy functions of land use dispute resolution, multiple use project development, ability to take rapid action and selective use of public funds, promotion of local capacity for resource stewardship, and facilitation of environmentally sound coastal design, when exercised in concert, have proven effectiveness and applicability, suitably adapted, to other coastal situations in which similar problems exist.

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Saving San Francisco Bay: California's *Other* – and first – Coastal Management Program

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ABSTRACT

California is the only state with two distinct coastal management programs for two different geographic segments of the state's coastal zone — each program administered by a separate state agency operating under its own unique enabling and policy legislation. The California Coastal Commission has authority over the ocean coastline segments of the coastal zone, and the San Francisco Bay Conservation and Development Commission (BCDC) has authority over the management of San Francisco Bay.

BCDC, which was established in 1965 as a temporary agency and made permanent in 1969, was used as a model for the Coastal Commission which was established as a temporary agency in 1972 and a permanent agency in 1976. Both commissions were given interim regulatory authority while they prepared long-range plans, both relied on the same consensus-building approach to formulate their plans, and the same individuals served in key executive positions in both agencies.

Although many observers are familiar with the Coastal Commission, fewer know that BCDC was California's — and the nation's — first coastal management agency, and understand BCDC's current role in California's coastal management effort. This paper summarizes how coastal management was initiated in California and explains how BCDC and the Coastal Commission work together as partners in implementing California's coastal management program.

International Perspectives on Coastal Ocean Space Utilization
Phyllis M. Grifman and James A. Fawcett, Editors

THE BEGINNING OF COASTAL MANAGEMENT IN CALIFORNIA

Although there are some differences, the events, approach and cast of characters involved in the early days of California's two coastal management programs have many similarities and a surprising number of identical elements.

The move to save San Francisco Bay was set in motion in 1959 when the U.S. Army Corps of Engineers released a report which indicated that 325 square miles of San Francisco Bay were "susceptible to reclamation" (i.e., easy to fill).[1] Alarmed by this conclusion and backed by the findings of an interim commission set up to study bay protection, in 1965 citizens in the Bay Area convinced the California Legislature that a temporary San Francisco Bay Conservation and Development Commission (BCDC) should be established to regulate new landfills in the bay and prepare a plan for the permanent protection of the bay.[2]

Governor Edmund G. "Pat" Brown appointed Melvin B. Lane, publisher of the popular *Sunset* magazines and books, as BCDC's chairman. The Commission, in turn, appointed Joseph E. Bodovitz, a San Francisco journalist and urban affairs activist, as its executive director and E. Jack Schoop, a professional planner, as its chief planner. The McAteer-Petris Act — BCDC's enabling legislation — required the Commission to submit a *San Francisco Bay Plan* to the California Legislature in 1969. The Bay Plan was developed by studying a series of issues, encouraging extensive public involvement and revisions to reach near-consensus on the policies for dealing with each issue, and then applying the policies to specific geographic areas. Because the Commission was empowered to regulate development while it prepared its plan, BCDC based its plan policies on its first-hand experience in dealing with actual development proposals, making the plan pragmatic and realistic. The Bay Plan called for making BCDC a permanent regional agency with authority to regulate bay filling and dredging, to encourage shoreline development that would increase public access to the bay, and to use shoreline property wisely in order to minimize pressures for further bay filling. In 1969, the Legislature amended the McAteer-Petris Act to make BCDC permanent and to incorporate the policies of the Bay Plan into law.

Based on the success of BCDC, California environmentalists approached the Legislature in 1969 with the idea of setting up a temporary coastal agency to deal with the uncoordinated and rapid development along California's 1,100-mile ocean coastline. Development interests, working with local governments who depended on continued growth to expand their tax bases, kept the coastal legislation bottled up for four legislative sessions. In desperation, the coastal protection backers took their proposal directly to the people in the November 1972 general election in the form of Proposition 20. Despite well-heeled opposition, the measure passed, establishing the California Coastal Zone Conservation Commission in 1973.

Governor Ronald Reagan appointed Melvin B. Lane to serve on the new coastal commission, and the Commission quickly elected Mr. Lane to serve as its chairman. Joseph E. Bodovitz left his post at BCDC to become the coastal commission's executive director, and E. Jack Schoop returned to California from

Wisconsin to head up the coastal planning effort. Utilizing the same combined regulation/planning approach that had proven successful at BCDC, the coastal commission delivered its *California Coastal Plan* to the Governor and the Legislature by the 1975 legislative deadline. The plan called for establishing a permanent coastal commission to carry out the extensive and detailed plan policies and recommendations. The Legislature culled the principal policies out of the plan and enacted the California Coastal Act of 1976, which established a new California Coastal Commission to carry out the policies of the act by regulating coastal development and overseeing a "local coastal program" effort to bring local government plans into conformity with the policies of the new state coastal law.

In 1977, both of California's coastal management programs were among the first state programs approved by the U.S. Department of Commerce as meeting the requirements of the federal Coastal Zone Management Act of 1972. The two programs were approved in separate federal actions, and California remains the only state with a federally-approved coastal management program that relies on two independent agencies to manage two geographically distinct segments of the coast under two distinct state laws.[3]

BCDC'S MAJOR RESPONSIBILITIES

In the mid-1960s, the San Francisco Bay region was beset with most of the problems typical of rapidly urbanizing areas in America. Affordable housing was in short supply, traffic congestion frustrated economic growth, and academic studies began to raise questions about the wisdom of unbridled urban development. But the San Francisco Bay region was unique in one respect. The history, culture and identity of this vast metropolitan area were tied to the existence of a single natural resource of national importance — San Francisco Bay. Despite its significance, the bay was being filled to accommodate housing, industry, ports, freeways and garbage dumps, and simply to add land thought to be needed for the continued economic well-being of the region.

BCDC was established to deal primarily with the uncontrolled filling of San Francisco Bay. To accomplish this, the Commission can issue fill permits only for water-oriented development and in the case of small amounts of fill, for public access to the bay and improved shoreline appearance. BCDC also controls the excavation of material from the bay. This authority has become more important of late because dredging and dredged material disposal have become increasingly difficult problems in recent years. The Commission is also empowered to control shoreline uses within "priority use areas" that are needed for water-related uses to ensure that these areas are not pre-empted for ordinary uses that could be located inland.

The other major responsibility of the Commission is ensuring that new shoreline development, whether along the existing waterfront or on new fill, provides maximum public access to the water's edge. The issue of public access is linked to bay fill. With past uncontrolled filling of the bay, there was little reason to provide access to the shoreline; a waterfront site could end up some distance from the shoreline as long as new fill could be be placed in the bay. In turn, providing public access to the shoreline has served to guarantee that further fill projects are resisted. Restaurant owners with bayfront dining areas, hotel operators with bayview accommodations and public park districts that have invested in building shoreline trails have a strong incentive to oppose landfill projects outboard of their investments.

BCDC has other responsibilities, most importantly, the protection of the Suisun Marsh, a 55,000-acre wetland. But this and other Commission responsibilities are either interrelated with or secondary to limiting bay fill and providing access to the bay.[4]

BCDC'S ORGANIZATIONAL STRUCTURE

BCDC has 27 members, five (including the chair and vice chair) appointed by the Governor, two appointed by the Legislature, two from federal agencies, five from other state agencies, and 13 appointed by local governments. Appointed alternates are permitted to attend meetings on behalf of absent commissioners. Beyond being reimbursed $100 per meeting to cover their expenses, the commissioners are not paid to serve on BCDC.

With almost half the membership made up of local government representatives, it might seem that the Commission would be parochial in its approach to facing regional issues. This has not proven to be the case in large part because the Bay Area is one of the more politically progressive regions of the nation. Furthermore, the local government officials who are willing to spend the time serving on the Commission are, for the most part, those who are interested in regional affairs. As a result, the local government representatives do not generally seem to regard themselves as protectors of local interests that are being challenged by an unwanted and intruding state agency. Instead, they recognize that there is a legitimate role for the state in protecting a natural resource of statewide and national importance. Many of the local government representatives have served on BCDC for several years and have provided political continuity that has balanced the Commission as governors and their appointees have changed.

Although there was some initial concern that the large size of BCDC's commission would prove unwieldy, the benefits derived from the diversity of the interests represented has outweighed the occasional difficulty in achieving a quorum. Furthermore, political observers seem to feel assured that all relevant concerns will be reflected in the Commission's consideration of an issue because BCDC includes representatives from most of the political elements that are interested in bay issues. Because the Commission has relatively little flexibility to misinterpret its mandated policies, many of its decisions reflect a virtual consensus of the entire membership present. This pattern adds credibility to the Commission's decisions and discourages divisive political efforts to intrude into or overturn BCDC conclusions.

The large size of the Commission has also proven to be a considerable deterrent to special interests trying to lobby individual commissioners on specific issues. With the 54 members and alternates, it is difficult to put a coalition together on any one issue and be assured that the right individuals will attend the relevant commission meeting. Rather than deal with this difficult logistical problem, special interest representatives have focused their efforts on trying to influence the Commission's staff analysis. By using professional staff to insulate the commissioners from external political pressures, the Commission can consider political issues without being dominated by them.[5]

BCDC'S JURISDICTION

To control the filling of San Francisco Bay, BCDC has regulatory jurisdiction over all areas around the bay that are subject to tidal action, the mouths of specified streams and rivers that flow into the bay, salt ponds, and diked wetlands that are used for duck clubs, game refuges or agriculture. To reduce pressure to fill the bay for water-related uses, BCDC's 1969 Bay Plan recommended that the Legislature give the Commission permit authority over development within shoreline "priority use areas" which the Commission found were particularly suitable and needed for ports, water-related industries, and airports. Elsewhere, to ensure that public access would be provided to the bay shoreline in new development projects, the Commission asked for jurisdiction over the first 1,000 feet inland from the shoreline. The Legislature believed that the Commission could carry out its responsibilities without such expansive authority. Therefore, the McAteer-Petris act provides BCDC with so-called "shoreline band" jurisdiction over only the first 100 feet inland both within the priority use areas and around the rest of the bay.[6] The federal approval of BCDC's program has enabled the Commission to use its "federal consistency" authority to prevent inland uses that would conflict with its policies. However, the Commission has not had to make extensive use of this power to achieve its goals.[7]

BCDC'S ACCOMPLISHMENTS

Despite its limited geographic jurisdiction, BCDC has been largely effective in achieving its primary goals of limiting new bay fill and increasing public access to the bay shoreline. When BCDC was established in 1965, San Francisco Bay was being filled at a rate of about 2,300 acres each year. BCDC has reversed this trend by requiring that diked areas be opened to the bay to mitigate the adverse impact of new fill projects that BCDC authorizes. In this way, over the past quarter century the Commission has been able to actually increase the size of the open waters of San Francisco Bay.

BCDC had hoped that by reserving the priority use areas for their designated uses, the need for new bay fill for these uses would be reduced. But because the Legislature provided the Commission with jurisdiction extending only 100 feet inland, it would seem that the Commission could easily have been frustrated in achieving its goal. That has not proven to be the case for four reasons.

First, the original priority uses area designations were based on local governments plans and zoning ordinances. Therefore, even though BCDC has little authority to prevent misuse of the areas, by stressing the importance to local governments of exercising controls to advance their own plans, many inappropriate intrusions in priority use area have been avoided.

Second, since 1965 the foundation of the San Francisco Bay region's economy has shifted from heavy industry to high technology and service industries. As a result, there has been very little demand for space for new water-related industries or for additional bay fill to accommodate this demand.

Third, after an initial rapid rise in Pacific Rim trade during the 1960s and 1970s when some additional fill was authorized so the Bay Area ports could incorporate container technology into their operations, the increase in Pacific Rim trade has been more modest. Further, the Bay Area is at a geographic disadvantage when competing with other west coast ports for Pacific Trade. Pacific Northwest ports are closer to Asian destinations, and Los Angeles basin ports serve a larger local market and have better rail connections to the rest of the United States. As a result, Bay Area ports have not proposed many large fill projects in recent years.

Fourth, during the 1950s and 1960s large areas of the bay were diked off to allow the region's airports to expand to handle increased air traffic. During the 1970s and 1980s, the emphasis in air transportation moved from expanding airports to making technological improvements and getting better utilization out of the existing ground facilities through measures such as better ground transport to airports and larger planes. As a result, airport expansion has been accommodated in the areas diked off from the bay prior to the establishment of BCDC.

BCDC's achievements in increasing public access to the bay are also impressive. When the Commission was established, only four miles of the bay shoreline were open to public access; this has increased to over 100 miles today. As is the case with reducing bay fill, BCDC has been able to achieve its goal of providing new public access to the shoreline with only 100 feet of dry land jurisdiction. In part, this success results from the bay region being heavily urbanized with public roadways near much of the shoreline and single properties stretching from this road network to the water's edge. This pattern has made it possible for BCDC to include conditions in the permits it issues for shoreline development which require access from a public road to the public shoreline. This situation has allowed BCDC to secure useable and accessible shoreline access despite its limited geographic jurisdiction. Moreover, some of the new public access to the bay is within public parks that have been established over the past two decades. For example, the Golden Gate National Recreation Area, which was established in the 1970s and is the most popular facility in the entire National Park system, includes many waterfront trails and shoreline facilities within. Although the access provided in the public parks does not directly result from BCDC's regulatory program, the Commission has played a major role in drawing attention to the bay and making the bay shoreline a national recreational treasure.[8]

EMERGING THREATS TO SAN FRANCISCO BAY

BCDC has been successful in reversing the shrinkage of the bay's size and dramatically increasing the opportunities for public access to the bay's shoreline. But other problems continue to threaten the health of San Francisco Bay.

A vast network of dams, canals and pumps diverts much of the fresh water that would flow into the bay under natural conditions. The diverted water is used to water crops and serve urban areas. There are proposals to increase the amount of fresh water being diverted from the bay to meet the demands of agriculture and California's growing population, which could result in less water being available to the bay and could endanger many species who rely on the delicate mixture of fresh and salt water that exists in the bay estuary.

Polluted water flowing into the bay also remains a problem. Although there has been considerable progress in improving the quality of the bay's water through better treatment of sewage, the water that drains from agricultural lands into the rivers that empty into the bay and from urban areas surrounding the bay still carry contaminants which threaten bay fish and wildlife.

Just inland of BCDC's jurisdiction, a vast mosaic of fresh water marshes, seasonal wetlands and agricultural lands is vulnerable to destruction Much of this area was once part of San Francisco Bay, but was diked off for other uses. In addition to serving as a buffer between the bay and urban areas, these diked historic baylands represent the last opportunity mankind has to increase the natural resource value of the bay. BCDC does not have jurisdiction over development in these areas which are being increasingly threatened now that other more suitable building sites have been developed.

Because much of the bay is shallow, it is necessary to regularly dredge channels and berths to accommodate the ships that call at the bay's ports. New ships are being built solely for Pacific Rim trade. Because these vessels do not have to fit through the Panama Canal, they are considerably larger than the ships that have traditionally entered the bay. A huge amount of material has to be dredged from the bay to accommodate these new deep-draft vessels. But it is difficult to find a place to dispose of the great quantity of material, some of it polluted, that must be dredged. For many years, the dredged mud was dumped in the bay near Alcatraz Island because it was believed that much of it would wash out to sea. However, the disposal site became a navigational hazard when too much material accumulated there. This situation led to investigating other dredged material disposal solutions, including placing the material in more sensitive areas and again allowing parts of the bay to be filled.

Traffic congestion throughout the bay region has also led to renewed proposals to build roads on fill in the bay, adjacent salt ponds and marshes. Although the Commission can authorize new bridges to be built to span the bay, it cannot legally approve solid fill for roads. Despite this legal prohibition, bay fill proposals are being investigated to relieve the daily frustration many people face in dealing with traffic.

These issues demonstrate that despite BCDC's success in achieving its primary objectives, saving San Francisco Bay is an unending battle.[9]

LINKAGE BETWEEN BCDC AND THE COASTAL COMMISSION

At noted, in 1977 BCDC's and the Coastal Commission's management programs were approved by the U.S. Department of Commerce under the provisions of the federal Coastal Zone Management Act of 1972 (CZMA). Shortly after the programs were approved, in the spirit of bureaucratic tidiness, the federal government required California to investigate whether the two programs should be combined. In 1978 the consultant who conducted the required evaluation concluded there was no analytical or political support for merging the programs.[10] The idea of combining the two commissions has never re-emerged.

Despite the decision to maintain BCDC and the Coastal Commission as independent legal entities, the two agencies have several ties which allow them to work together to achieve their common goals. A memorandum of agreement sets out how communication and coordination between the two commissions is handled. Although the federal government was willing to accept the commissions' decision to not merge the agencies, the CZMA requires that only one state agency can be the primary applicant and recipient of CZMA grants. Therefore, BCDC applies for its federal funds as part of the Coastal Commission's application and receives these funds on a reimbursable basis from the Coastal Commission. Because BCDC is a very small agency (a staff of 26 and a budget of about two million dollars), the Coastal Commission also handles BCDC's personnel and accounting responsibilities on a contractual basis. In addition to these ongoing relationships, the commissions use ad hoc arrangements to work together on specific proposals, such as dredging projects where material dredged from the bay is disposed of in the Pacific Ocean. The two commissions also co-sponsor "Coastal Clean-up Days," "Coastweek" events, and other activities of common interest.

Beyond these formal arrangements, the staffs of the two commissions have a very close informal working relationship. Both commissions use the same civil service classification to hire most of their staff. This has resulted in a number of individuals having worked for both commissions at different times in the course of their professional careers.

CONCLUSION

Perhaps the most telling evidence of the effectiveness of BCDC as a full partner in California's coastal management effort is the number of times BCDC has been used as model for other resource management programs. BCDC was used as the model when Californians decided to "save the coast" in the early 1970s. In 1977, BCDC was used as a model for legislation to protect Japan's Inland Sea from unregulated filling.[11] And on the eve of the twenty-first century, as the San Francisco Bay region grapples with how to manage its growth and protect its resources, once again BCDC is being used as a model. The Bay Vision 2020 Commission has recommended that a large and diverse commission should be established as a temporary agency, given three years to prepare a regional plan, and given interim regulatory authority while the plan is being prepared.[12] BCDC continues to be imitated largely because it has achieved the admirable record of having accomplished precisely what it was set up to do save San Francisco Bay.

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California Ocean Use Management: An Assessment of Two Integrating Approaches

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ABSTRACT

The conflicts among the multiple users of California's ocean and coastal zone have made management of this unique state's natural resources problematic. Policy makers have failed to "internalize externalities" — to balance the interests of the various users and act in a coordinated fashion to solve problems — and have yet to develop an integrated approach to ocean and coastal zone management. In this essay, we will briefly review the fragmented responsibilities and activities of the state agencies involved in managing California's ocean and coastal resources. We will concentrate on two fundamental mechanisms for encompassing externalities and balancing diverse interests — ad hoc organization and regional organization. Scholars and policy makers have recommended both. Regional organizations cover all or part of several states and may be comprised of state, federal and/or local governments. Regional organizations have been justified in the United States in that they provide coordination and centralization in a federal system which often can be described as fragmentary and conflictual. Ad hoc organizations have been recommended by federal and state environmental law and can also be made up of federal, state and/or local governments. We suggest that different forms of integrating mechanisms are appropriate for different ocean and coastal policy areas; and different social principles will govern the decision making and planning process.

International Perspectives on Coastal Ocean Space Utilization
Phyllis M. Grifman and James A. Fawcett, Editors

INTRODUCTION

Intense conflict found among users of the ocean and coastal zone have led to the specific problem of the need for coastal zone administrations to "encompass externalities." In other words, coastal zone planners have yet to adjust and accommodate to those interests not represented in decision making processes. California's ocean and coastal managers have found it difficult to act in a coordinated fashion to solve problems, which often entails working with the federal government and with local governments who often bear the majority of costs. This essay will review two integrating mechanisms — ad hoc and regional organization.

CONFLICT AND COMPETITION IN THE CALIFORNIA COASTAL ZONE

The California coastal area supports a number of activities such as energy production, recreation, transportation and commerce, national defense, and commercial fishing.[40] Each of these activities is significant in and of itself, contributing greatly to the economic strength and quality of life of the state. Yet, each activity often "bumps" into the others, leading to disputes among the multiple users of the coastal zone and its adjacent marine area. Conflicts are exacerbated by the intensity of use and the proximity of uses endemic to the coastal zone. Much of the coastal zone of California is densely populated, with major population corridors extending from San Diego to north of the San Francisco Bay area. Furthermore, most uses occur within relatively close proximity to the coastline, increasing the likelihood of users pressing demands for exclusionary access to coastal and ocean space.

In addition to multiple uses, the area is one of multiple intergovernmental and intragovernmental jurisdictions. Local governments within California have a great deal of authority over land use decisions within their respective political boundaries, which generally end at the intertidal zone. State jurisdiction extends from the coastline seaward three nautical miles. Federal jurisdiction generally extends seaward from the three mile state limit. In response to the challenges posed by these uses and the conflict arising from them because of spatial proximity, California state government regulates the uses, employing traditional hierarchical agency-department bureaucratic structures with authority extending to the limits of the three mile state waters.[39] Reflecting the federal government organization scheme, management of resources is sectoral (i.e., a separate department regulating each use such as fisheries, energy development, etc.). Conflicts between sectors must often be resolved through the agency-department hierarchy. While reliance on bureaucratic means to resolve conflict is the general defining characteristic of state and federal management systems, there are circumstances when cross-jurisdictional conflict requires cross-jurisdictional solutions.

There is a nexus of multiple uses, the potential for conflict, and multiple jurisdictions in offshore energy development. There are many potential impacts associated with offshore development that affect every other use. Given the cross-jurisdictional nature of this development, traditional local, state and federal bureaucratic decision making structures may need to be augmented by multi-jurisdictional organizations. An example of this is the ad-hoc structure created to develop environmental impact analysis for offshore energy development.

AN INTRODUCTION TO THE AD-HOC ORGANIZATION AS AN INTEGRATING MECHANISM

A single, preferred organizational form for conducting environmental impact analysis (EIA) has not been developed, although a preference not to isolate EIA in planning or staff groups has been expressed. This gives rise to a hypothesis that a type of ad-hoc administrative arrangement is needed to conduct EIA.[4]

Ad-Hoc Organizational Structure

Generally, three forms of ad-hoc administrative arrangements have been identified: Task forces, Task teams, and Matrix organizations. Common motivations for adopting these forms is the desire to overcome coordination and communication problems which result from the division of labor within, or in an intergovernmental context, between organizations. The simplest form of ad-hoc structures is the task force. Essentially, task forces are committees which are established to coordinate a particular project or solve a particular problem, disbanding once the task is completed. Task teams are similar to task forces, but are permanent, similar to standing committees within many organizations. The matrix organization is more complex than either the task forces or teams.[22] When an organization habitually employs a system of interdisciplinary teams centered around discrete projects, it is often referred to as a matrix organization,[4] although one scholar suggests a typology of matrix organizations which will encompass task teams as a form of matrix organization,[48] while another suggests that, in some cases, matrix organizations evolve from organizational experience with simpler forms of ad-hoc organizations.[21] For discussion, the term "matrix pattern" will encompass the three aforementioned types of ad-hoc organizations.

Matrix pattern organizations have two distinguishing features, dual authority and balanced power. Dual authority means that members of the organization have a dual reporting relationship; that is, two managers to which they are responsible. While this characteristic violates the principle of unity of command, it is viewed as being appropriate for conditions under which the matrix pattern will be effective.[22] Balanced power encompasses the principle that relative power between the two managers defining the matrix should be approximately equal. While achieving balanced power may be problematic, it is necessary for dual authority to have any validity. Without balanced power, one manager would be able to dominate or unduly influence members of the matrix.[22]

Analysts have identified three conditions which "pressure" organizations towards a matrix pattern; outside pressure for a dual focus, need for high information-processing capability, and pressures for shared resources.[30] The presence of these conditions in major offshore energy development projects has led to the creation of ad-hoc formal organizations exemplified by the joint review panels (JRP) formed during the 1980s to produce environmental assessments for offshore energy projects.

Evolution of Joint Review Panels

Joint review panels have been described as "experiments with quiet incremental reforms."[18] Use of the joint review panel was pioneered by Colorado initially as the result of a ski resort siting dispute and in subsequent application to major energy and mineral resource projects. In the latter application, the JRP sought to "coordinate regulatory and administrative reviews conducted by the three levels of government, thus expediting those review processes and improving the quality of project planning and review.[11] Initial application of the panels in California coastal development occurred with its application to offshore energy projects in the eastern Santa Barbara Channel in the 1970s.

Benefits of offshore development are usually realized at a national or state level while costs are often borne at the local level.[40] Also, energy development in the channel usually requires permits issued by federal agencies for platforms and pipelines placed on outer continental shelf leases; state agencies for pipelines across state submerged lands, coastal development permits, etc.; and local agencies for related onshore facilities.[38,50]

Prior to JRPs being utilized, separate environmental reviews were conducted by each cognizant level of government. This system had two immediate results. Local governments believed that their interests were not adequately addressed in federal and state level reviews. Furthermore, the duplication and overlap inherent in separate reviews and the resulting delays in permit processing caused widespread dissatisfaction with the review process.[27]

Provisions of the National Environmental Policy Act (NEPA), the California Environmental Quality Act (CEQA), and the California Permit Streamlining Act encourage the production of a single environmental document that will satisfy local, state, and federal requirements. Intergovernmental coordination in the preparation of environmental documents for the onshore and offshore components of Chevron's Santa Clara Unit, facilitated through responsibilities outlined in memoranda of understanding (MOU) is credited with allowing project permitting to proceed in a timely, orderly fashion.[23] While this mechanism was not a formal JRP, it established the system for and demonstrated the tangible benefits of intergovernmental cooperation.

The major responsibility of joint review panels is to oversee preparation of an environmental impact assessment document that satisfies the requirements of NEPA for federal agencies and CEQA for state and local agencies. The JRPs do not issue permits. Rather, they produce an analysis which provides permitting agencies the information needed to approve projects and issue permits in accordance with federal and state environmental law. This information includes probable impacts from development and suggested measures to mitigate the impacts.

The first panel was established for the siting of Platforms Gina and Gilda off the Ventura coast and was made up of agencies having any permitting authority over various project components. Involvement of numerous agencies made the environmental impact assessment process unwieldy[31] and is credited with actually hindering the project's development.[43] However, the experience from each of these projects incrementally changed the system for conducting environmental impact analysis. The next application of the JRP with the Exxon Santa Ynez Unit project in 1983 proved to be more successful and signified the beginning of widespread use of joint review panels to conduct analyses for offshore energy projects.

Analysis of more than 10 panels formed to oversee preparation of environmental documents for development in the area offshore of Santa Barbara County indicates the panels were very effective in meeting the needs of the agencies involved in offshore energy, although the panels were not without their problems. In fact, agencies have become conditioned to expect a JRP when new offshore energy projects are proposed.[19] Other analysts note the JRP has facilitated the inclusion of local interests in decision making;[1] have been a "substantial success" in resolving incompatible or competing mandates and goals and/or overlapping jurisdictions[9] and suggest that use of panels may resolve conflicts between energy development and other users by ensuring mitigation or compensation is provided.[28]

Nature and Structure of the JRP

The offshore energy JRPs have been comprised of representatives from the federal, state, and local governments exercising major primary permitting responsibilities for project components. These agencies include the Minerals Management Service, California State Lands Commission, California Coastal Commission, the California Office of Planning and Research (Secretary of Environmental Affairs Office of Offshore Development in later panels) and the Santa Barbara County Resource Management Department (the land-use planning agency). Although any agency which has permitting authority over any part of the project is eligible for membership on the JRP, membership is usually defined in terms of level of jurisdiction over project components. Disputes over membership have the potential to jeopardize efficient task completion.[1]

The panel operates under a Joint Review Agreement (JRA) which specifies panel member responsibilities, time frame for completion of the panel's task, and extent of the panel's decisions. The panel selects and directs the contractor who produces most of the analysis and documentation. One member of the panel is designated lead agency (co-lead agencies have been used on some projects) to direct the panel in its tasks and make final decisions on key issues including the required level of impact mitigation.[1]

Participation in the JRP is voluntary. Each member has the right to withdraw from the panel and pursue its analysis independently. While there is a possible erosion of a government's ability to singularly manage the project when it serves on a JRP,[24] the advantages which accrue to members are numerous. The JRP allows jurisdiction problems and policy differences to be worked out at staff level, enhances sharing of expertise, provides the means to evaluate multi-level benefits and costs, and coordinates various land-use, development, and environmental regulations.[32]

Consensus decision making among panel members is the preferred method of dispute resolution. Most JRPs have operated solely by consensus, with voting mechanisms specified in the JRA used sparingly as a last resort.[19] This characteristic has resulted in JRPs being described as "reflective bodies."[42] A portion of this tendency may be attributed to the nature of committees which views decision making as "a matter of invention, rational discussion, compromise, and eventual agreement on the best practical solution."[2] Another influence on the consensual deliberations is the presence of a facilitator on JRPs. The representative of the Office of Planning and Research/Secretary of Environmental Affairs mediates differences between panel members to prevent the necessity of a vote from ever occurring.[31] JRP participant interviews indicate generally positive attitudes toward the facilitator.[19]

Ad-hoc Organizations and JRPs

As initially established, the JRP exhibits characteristics of a task force organization. Several different agencies, each with a different and potentially conflicting mandate come together to solve a single problem — production of an environmental impact assessment for a single project.

With continued use of the JRP to evaluate several projects in a relatively short period of time, the organization begins to exhibit characteristics of a task group. With each repeated application of the technique, agency roles and organization procedures become more routinized. As learning occurs, organizational efficiency improves.

Members of task forces and task groups are influenced by the hallmarks of matrix pattern organizations — dual authority and balanced power. Dual authority is present in that each agency representative is responsible to their respective agency supervisor and the JRP's lead agency representative (who essentially acts as project manager). Balanced power is achieved through the JRA which favors consensual decision making while giving the lead agency paramount powers in final decisions when needed. The voluntary participation aspect acts as a veto point balancing power towards the member agencies. The presence of a facilitator will act to mitigate a preponderance of power as will the self-view inherent in committees.

As noted above, outside pressure for a dual focus, need for high information-processing capability, and pressures for shared resources are influences which foster matrix-pattern organizations. The dual focus involved in offshore energy projects is the need to fulfill the mandate of the agency, be it the development of energy sources or the protection of local health and safety and the need to produce an acceptable environmental impact assessment. High information processing capability is required for the voluminous data which must be generated in the assessment. Shared resources are required to control the costs associated with assessment, to eliminate duplicated effort and politically embarrassing project delays, and because the "sharing" is mandated by federal and state policies.

There are incentives for participating in a JRP. Among the most important is the ability to influence multi-level outcomes in both the definition of problems and the preferred solutions. For example, the panel defines conditions which constitute environmental impacts to be addressed by the assessment. Given the different orientations of agencies and the uneven distribution of benefits and cost of offshore energy, a condition may be recognized as a problem at one level of government, but not at another level of government. Additionally, mitigation measures identified in the assessment are seldom implemented by a single agency or by a single level of government. Furthermore, the mitigation measure preferred by one level of government may be implemented by another level of government. Thus, the ability to influence the classification of impacts and the measures used to mitigate the impacts provide a strong incentive to participate in the panel.

For those issues which are regional and transboundary in nature, e.g., fisheries and pollution control, an interstate mechanism may be more appropriate than an ad-hoc mechanism. Many environmental problems which contemporary society faces transcend political boundaries and a different encompassing mechanism may be called upon.

THE REGIONAL INTERSTATE ORGANIZATION AS AN INTEGRATING MECHANISM

The management of the ocean and coastal zone is one example of a concern which is regional in nature. Regional organizations cover all or parts of several states and have been justified in the United States in that they provide coordination in a rather fragmented federal system.[16] Recently, scholars have recommended the interstate compact as a means to resolve multiple-use conflict in the Pacific ocean and coastal zone. Cicin-Sain, Hershman, Hildreth, and Isaacs suggested:

> There are a number of reasons why it is advantageous for coastal states to act regionally on common or shared ocean management problems. These include: 1) spillover effects (positive and negative) of ocean resource economic development in one state on other states; 2) the need for interstate planning for resources or uses that are transboundary;

3) the sharing of state experiences on common problems; 4) the promotion of standardized state policies/procedures that can encourage private investment; and 5) the development of a collective state approach for dealing/negotiating with the federal government.[10]

The broad interest in such compacts is based on the assumption that states can effectively pool their resources and cooperate to offset obstacles to environmental policy making.[7]

However, it is by no means clear that such regional compacts can reasonably be expected to work effectively. Effectiveness may depend on relatively special circumstances. Little if any systematic study of the efficacy of the regional interstate mechanism has been undergone. In addition, for a number of political and economic reasons, the federal government has been reluctant to entrust policy decisions to regional administrations, and many citizens dislike decisions taken by government officials not elected to office. Also, unless coerced into forming regional administrations, interstate administrative mechanisms would need to offer incentives to states to join (this is consistent with a wide range of work on group formation). Moreover, regional administrations may reproduce the many problems now facing present state-level ocean governing organizations.

Horizontal and Vertical Regionalism

In the U.S. federal system, it is useful to distinguish two types of interstate relationships, vertical and horizontal. Horizontal regionalism is essentially a lateral, non-hierarchical, and voluntary relationship.[54] It is a relationship between states which have entered into a formal contract which is often, but not necessarily, binding if it has Congressional consent. The issue of Congressional consent is somewhat vague and many horizontal compacts have flourished without such consent.[47]

Vertical relationships typically involve an active federal government participant — indeed, the federal government may well have organized the regional agency. The states are subordinate to the national government in vertical relationships. Because of federal sovereignty, there is the possibility of parties appealing decisions made in the framework of the commission to the relevant federal agency. In some cases, this may act as a barrier to consensus building. For example, pursuant to the Magnuson Fishery Conservation and Management Act of 1976, fishery management councils were created to conserve and manage the fisheries in several regions. Fishery management plans adopted by each council are given to the Department of Commerce for approval or disapproval and states that cannot agree at the council level are able to appeal to the federal government.

An Overview of the Use of Compacts

The use of the interstate compact appears to correspond with shifts in the role of the states in policy making. In the 1950s there was a rise in the use of the interstate compact because of the new dimension of state power in intergovernmental relations. Between 1950 and 1970 the rate of adoption of compacts accelerated to more than four a year.[44] During this period, several organizations recommended the compact, including the President's Council on Environmental Quality; the Committee on Economic Quality; the Brookings Institution and the Advisory Council on Intergovernmental Relations. After 1970, growth in the use of compacts fell dramatically.[13] Perhaps this decline can be understood partly as a response to the increased role the federal government played in policy making during the period. In the 1980s, under the philosophy of New Federalism, the Reagan Administration cut grants-in-aid for environmental projects[27] and there was a rearrangement of responsibilities along more decentralized lines.[14,20,49] The federal government began looking increasingly to the states to provide environmental policy innovation[14,15,20] and conflict over natural resources intensified. The Bush Administration continues to look to the states to resolve their particular environmental problems. In an attempt to adjust to complex environmental difficulties, states may begin to cooperate with other states by joining either interstate cooperative commissions or formal interstate compacts. For example, the California Assembly has passed a bill supporting the notion of an interstate compact to manage the Pacific coast region.[8]

Before investing the interstate compact with special responsibilities and high expectations, we need information on whether and when regional institutions are effective means of decision making. In general, literature on regionalism can be portrayed as skeptical about the effectiveness of such administrative mechanisms. One scholar maintained that "regionalism seems to flourish when the stakes are low and when there is no perception of winners and losers."[6] Ocean and coastal use conflicts are often zero sum games played out between users. For example, private interests proposing offshore oil development compete with commercial fishing interests and recreational users for the same space.[40] An ocean regional administration would have to contend with a myriad of user preferences located at the local, state and federal level.

The Cases

Three different cases of environmental regionalism are reviewed. Before developing the typology, it is important to note that the authors recognize that an argument exists against using land management principles for ocean management. The authors contend that policy makers can learn from the successes and failures of land management regimes. Each case was chosen because the issues the regional agency addresses transcends political boundaries and represents an example of the problem of integrating diverse interests. The Southwest Low-level Radioactive

Waste compact (SWLLW); Northwest Power Planning Council (NPPC); and the Pacific Fishery Management Council (PFMC) are compared in terms of primarily two endogenous variables, the structure of authority surrounding the regional agency; and the costs and benefits associated with the substantive issues the regional agency addresses.

Membership of the PFMC includes the states of Oregon, Washington, California and Idaho, representatives from state fishery agencies from each state, federal agency representatives, and citizens knowledgeable of fishery concerns. In fishery councils, costs are often concentrated and are found in the various commercial fisheries within the region. Public concern over fishery conservation is not as intense as it is regarding radioactive waste.

The PFMC is an example of the conjoint form which is predicated on a vertical relationship between states and the federal government. The states are subordinate to the federal government and individual member states can appeal agreements made in the agency at the federal level — which constitutes a veto point. The PFMC is subordinate to the Secretary of Commerce who approves or disapproves council decisions. Because of this lack of discretionary authority, the PFMC has no "implementation teeth"[10] and has been found to be ineffective in protecting the fisheries in its region.

The NPPC was formed in 1981 pursuant to the Pacific Northwest Electric Power Planning and Conservation Act and incorporates two members from each of the following states — Idaho, Montana, Oregon, and Washington (there is no federal representative). The NPPC has the unique authority to bind federal agencies — a rare constitutional power — to follow the guidelines adopted in the Fish and Wildlife Program adopted in 1982.[35,36] Costs of action are widely diffused because funding is provided by the utility companies and their costumers within the region.

The Fish and Wildlife Program adopted by the NPPC is grounded in the adaptive decision making process which represents an alternative to the traditional means of environmental assessment as depicted in the environmental impact statement.[29] In particular, the adaptive approach values a "trial and error" process of learning from mistakes and assumes that environmental assessment is an ongoing investigation and not a one-time prediction of impacts.[29] It has been suggested that the NPPC has been quite effective in implementing the program.[35,36]

Pursuant to the Low-Level Radioactive Policy Act of 1980, as amended, the SWLLW formal compact made up of Arizona, California, North Dakota and South Dakota has the unique authority to treat, package, ship, and dispose of low-level waste (LLW) — a power traditionally considered a federal responsibility. Each state participating in a LLW compact has to balance the interests of the local population bearing the costs and the local populations' interest of not-in-my-backyard (or NIMBY) against the interests of the region which receives the benefits.[34] The LLW compact may be a model for future compacts to emulate because concentrating costs at the local level may be necessary in other environmental areas.[34]

Due to the perceptions of risk related to low-level radioactive waste, each state is an adversarial representative of its own interests. Successful implementation of regional LLW compact decisions requires a completed and agreed upon environmental impact statement. To date, the SWLLW compact may be the first regional compact without a radioactive waste site to develop one[45] and a consensus has been reached between member states. The SWLLW compact has chosen Ward Valley, California for its first LLW repository and an EIA will soon follow.

A Typology of Forms of Environmental Regionalism

From the cases, a typology of three forms of environmental regionalism has been derived (Table 1).

Table 1

Characteristics of Regional Decision Making Forms

	Regional Forms		
	Adversarial	**Adaptive***	**Conjoint****
Case	SWLLW	NPPC	PFMC
Authority	Horizontal Shared	Horizontal Shared	Vertical Federal Sovereignty
Purpose	Single	Single	Single
Costs	Concentrated	Diffused	Concentrated
Perceived Risks to Social Welfare	High (LLW)	Low	Low
Process	Answer Oriented Competing Values	Question Oriented Competing Values	Information Gathering Competing Values

* Many of these characteristics were derived from Lee, Kai N. and Jody Lawrence, "Adaptive Management: Learning from the Columbia River Basin Fish and Wildlife Program," *Environmental Law* 16, (1986), p. 448.

** The term conjoint is derived from Welborn, David M., "Conjoint Federalism and Environmental Regulation in the United States," *Publius: The Journal of Federalism* 18, (Winter 1988)

We suggest that given federal and state environmental laws, a conjoint form of ocean regional decision making would evolve. The conjoint form, as depicted in the PFMC, is grounded in a hierarchical, vertical relationship between the states and the federal government. The federal government is the dominant force within a conjoint form of interstate regionalism and as an active participant and member of the compact would pursue its own interest. The local governments may not be given representation in such an ocean compact. But, the authors suggest that some means of encompassing the interests of industry, the public and the local governments should be developed into any regional form. The barriers to participation should be kept low throughout decision making. If not, the ocean regional planners may face the same problems facing state-level decision makers.

AN ASSESSMENT OF TWO INTEGRATING MECHANISMS AS ENCOMPASSING ORGANIZATIONS

As shown in Table 2 below, the characteristics of ad-hoc organization and the regional compact vary greatly, making each particularly well-suited to application as a mechanism to integrate interests in coastal zone disputes.

Table 2

Comparison of Ad-Hoc and Regional Mechanisms

Characteristic	Ad-Hoc	Regional
Problem	Localized	Widespread
Jurisdiction	Intrastate or Interstate	Interstate
Duration	Short-term	Long-Term
Policy Phase	Formulation	Formulation and Implementation
Purpose	Task Specific	Sector Specific
Authorization	Interagency Agreement	Formal Legislation

Ad-Hoc Ocean Organizations

Ad-hoc organizations such as JRPs, used to address coastal zone issues, appear to be most appropriate to well-defined, geographically localized situations. Though commonly composed of political entities within a state, the organization could conceivably be interstate in nature for transboundary problems. (However, variations in state environmental law, the extent of empowerment of local government and the potentially large size of the group could be fatal to the task of an interstate JRP.) Ad-hoc organizations are time-constrained organizations, they must accomplish their well-defined task in a specified period of time. As such, there are milestones to measure the groups performance. Simplicity enhances the attractiveness of this type of organization. While an informal agreement could structure group operation, a simple interagency agreement, though more formal, should unambiguously specify group relationships.

Task forces and task groups will most likely be the dominant form of ad-hoc organizations used to address management questions. The ultimate matrix organization is more complex and permanent than task forces or groups, making it an organization of last resort. A pure matrix, with its inherent problems of balanced power and dual authority, may not be appropriate to address the constantly changing and uncertain problems which arise from the coastal zone.

Ocean Regionalism as an Integrating Approach

There are two ways in which an ocean regional administrative mechanism could be formed. First, if the necessary incentives are offered, each state could voluntarily join an interstate agency. The issue of whether or not such a interstate agreement would require Congressional consent remains unclear. Second, in the event that Congress passed legislation to create interstate compacts for the regional management of the ocean and coastal zone, each state could be coerced to join a regional compact.

Given the complexity of a potential ocean regional administration, we have identified several concerns pertaining to the maintenance of the organization.

With respect to a potential ocean regional agency, the essential issue is whether or not the agency has autonomous decision making authority. Authority matters more in situations with difficult cost/benefit tradeoffs such as those found in ocean use conflict. In such situations, the agency itself will find it difficult to make compensation payments and compel agreement. With regard to the level of discretionary authority, the efficacy of an ocean regional administration involves three potentially separable issues. First, can the participants in the agency make a final decision that cannot be appealed to another governmental level (i.e., the federal government)? Second, does the agency possess any capacity to implement its decisions? Third, are other actors required by law to acknowledge the decisions reached in the agency and regard them as binding?

Different patterns of costs and benefits arising from the substantive problems under consideration are also likely to affect how ocean regional agencies work (this is consistent with a wide range of work on bureaucracy).[53] Some costs receive special political standing because of the high perceived risk associated with the cost, e.g., potential offshore oil development. Perceived costs are often related to perceived risks. Perceived risks do have an impact on policy making. In general, when risks are perceived to be high, (i.e., there is perceived significant cost to social welfare), the regional organization will act rather than continue to bargain in the pursuit of consensus between participants. When risks are perceived to be low (i.e., there is a perceived insignificant cost to social welfare), the no-action presumption (doing nothing is better than doing something) is acceptable and the bargaining process continues. In many ocean and coastal policy conflicts, perceived risks may force the regional agency to act.

The role of a potential policy fixer[3] may enhance a potential ocean regional agency's ability to effectively administrate. There are two types of policy fixers — the patron and leader. The patron operates outside of the regional agency and is not a member of the regional agency while the leader acts within the organization to help maintain the organization. The presence or absence of either policy fixer may have an impact on the ability of the regional agency to effectively achieve formal and informal goals. Interest groups and officials in other government bodies not represented in the regional agency may have an impact on planning.

Few regional agencies provide for their own operating revenues and must rely on external financial support. In light of New Federalism, we suggest that federal funding would have a significant impact on ocean regionalism and believe that the "power of the purse" can constrain or induce effective administrative behavior.

Size of the regional agency is of fundamental importance. Large, multiple purpose forms of regionalism would need to encompass more interests and internalize more externalities than single purpose administrations. Local governments might be provided with the authority of "consultation and concurrence" as depicted in the Nuclear Waste Policy Act of 1982 (states have the authority to veto the federal government's proposed plan to develop a high level nuclear waste repository within their jurisdiction). Local governments could also be given such authority in multiple use ocean management regimes. Local governments could also be given representation within the regional compact (see, for example, McGinnis[41] on intrastate regional compacts).

SUMMARY

In California, there is the need to develop an administrative mechanism which would allow the various interests and users of its precious natural resources to be integrated. We have reviewed two major mechanisms for encompassing externalities and have elaborated on both. Several key forms of the ad-hoc and regional organizations were characterized. Given such a characterization, we have hypothesized that different forms of either the ad-hoc or regional administration would develop in light of current state and environmental laws. Obviously, neither mechanism can completely represent the interests of all the users of coastal and ocean space. Nor does using either structure guarantee that interests will be integrated. However, each offers the potential to improve the existing hierarchical decision making structures.

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An Assessment of Coastal Multi-Use Management and Training Programs in Rhode Island

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ABSTRACT

The integration of coastal zone management planning at the municipal level has been the focus of harbor management planning in Rhode Island for several years. A fundamental goal of this work has been to implement effective management programs for the multiple uses of coastal waters and waterfronts. Cities and towns were divided into four groups based on the predominant uses of their waters and waterfronts and prototype harbor management plans were then developed for each harbor type. This process was spearheaded, and in-situ project leadership provided by the Rhode Island Coastal Resources Management Council, with the assistance of the Rhode Island Sea Grant Marine Advisory Service and the Coastal Resources Center.

Secondary goals included the implementation of education and training programs for town-level decision-makers and harbormasters. Members of each of these groups are routinely involved in a wide range of coastal multi-use issues, however many of these local office holders have little understanding, background, or knowledge of these topics. Effective municipal management can only be accomplished when local governments realize and appreciate the need for coordinating what happens in coastal waters with adjacent shoreside development and uses. Therefore, courses in Basic Training for Harbormasters and the Harbors Education Program have been developed to begin to fill the coastal issues information gap of local public officials.

This paper will present an overview of these three programs. Jointly, they comprise an integrated model of local coastal planning and education. These

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models are valuable to all waterfront communities that are trying to manage the diverse uses of their waters and waterfront. Each program will be analyzed based on program development strategies, implementation, and strengths and weaknesses based on participants' reactions and the experience of project leaders.

INTRODUCTION

The decade of the 1980s will be remembered as a time of commercial, residential and recreational growth in the coastal waters and adjacent lands of the United States and many other regions of the world. Rhode Island, the smallest and most densely populated state in the country, was not exempt from this growth. It could even be argued, that because of the size of the state, the dominant presence of Narragansett Bay, and the fact that no Rhode Islander lives more than 30 minutes from salt water, that Rhode Island is the ideal model to study many, if not most, of the conflicts and impacts resulting from the expansion of people and activities into the coastal zone. In 1988, in recognition of the seriousness of the stress being placed on the social, civic, ecological, financial and governmental aspects of coastal communities and waters, the Rhode Island Coastal Resources Management Council (CRMC) initiated a program designed to achieve better management of local waters and waterfronts.

The CRMC was created by an act of the state legislature and given the responsibility for planning and managing the resources of the coastal region of the state.[1] The program developed by the council, known as the Rhode Island Harbors Project, was to provide the foundation for the development of municipal harbor management plans (HMP) and training for harbormasters and local waterfront decision-makers. As the project moved forward and more people began to participate in HMP meetings conducted by the CRMC it became evident that insufficient statistical, legal, and policy information existed on the full range of issues associated with coastal planning and management. This realization helped to define the guidelines and identify the type of assistance that each community would need in order to develop and implement a local harbor management plan. By providing long-term, hands-on technical assistance to each test community, CRMC differentiated itself from other agencies working on local harbor planning around the country.

Most of the issues identified in the harbor planning process included sections that proposed additional education for every group that was concerned with effective, economic and environmentally appropriate harbor and coastal management. Two groups stood out above all the others as being in a position to have a direct and immediate impact on the management of these coastal resources. These were municipal harbormasters and the members of local boards, commissions, and elected bodies. Harbormasters were deemed very important for two reason. First, they were the visible manifestation of authority on the waters and along the waterfronts of each community and second, their role as harbormasters had been shifting during the past ten to fifteen years. They were being asked to fulfill new functions requiring new skills, and a different background. Besides traditional knowledge of boats and moorings, they now needed to understand town financial and budgeting matters, serve as public relations specialists, grant writers, and be available on a 24 hour basis throughout the year.

Those persons serving as volunteers or appointed to such groups as municipal planning and zoning boards, conservation commissions, harbor committees, as well as elected officials and administrators, have very little exposure or understanding of what happens on the waters under the jurisdiction of the local government and even less of a familiarity with the relationship between those waterborne activities and what occurs on the adjacent shoreline. It is imperative that these individuals gain an insight into the differences between managing real estate and managing coastal waters and harbors. Because these persons can shape the direction of each community they were selected as the second target group for an educational program in coastal and harbor management.

HARBOR MANAGEMENT PLANNING

In 1983 the CRMC promulgated amendments to the state Coastal Resource Management Program that required municipalities to submit any changes in local waterfront ordinances to the CRMC for approval.[2] However, only a few communities complied and ultimately the authority of harbormasters and local governments to enforce waterfront rules, regulations and fees was challenged. The argument was made that harbor ordinances not having the approval of the CRMC were unenforceable. This opinion prevailed and subsequently most communities submitted their ordinances to the CRMC.

During the years this process was taking place moorings for recreational boats had literally filled up most of the protected harbor areas of the state. The mere presence of these moorings had now become a potential burden on the preservation of high water quality and they also interfered with shellfishing and swimming. All the while the demand for more mooring space was spiralling out of sight[3] harbormasters were being harassed by boaters and local residents, each group seeking to secure its position concerning the activities that happened on local waters.

The Rhode Island Harbor Planning Process

The Rhode Island Harbors Project implemented by the CRMC focused on providing assistance to cities and towns in the development of harbor management plans. It also served as a means to ease tensions and put aside long-standing misunderstandings among the users of these resources through group participation. Essentially, the CRMC modified a process that had been occurring for several years in various communities on the west coast and in other New England states. The first step for the council was to form a Harbor Management Guidelines committee that would draft procedures useable by local planners for the creation of a HMP. After writing the guidelines, which included a HMP requirements checklist, the CRMC commenced two actions that would differentiate it from other agencies working on local harbor planning. With the assistance of the Rhode Island Sea Grant Program Marine Advisory Service (MAS) and the Coastal Resources Center (CRC) of the University of Rhode Island, the CRMC conducted presentations before the city and town councils of every coastal community in Rhode Island. These informational sessions described what harbor management planning was, why it should be done and how the CRMC could help each town complete a plan.

The assistance provided by the CRMC consisted of supplying each community with the harbor planning guidelines, and, for those towns that began work on a local harbor plan, a HMP facilitator/technical advisor was made available. These advisors, employed by the CRMC, MAS and CRC, were experts in coastal management and became the leaders of local harbor planning efforts around the state. As trained coastal professionals familiar with state law and harbor planning guidelines, they performed a wide range of functions. They served as data gatherers, oversaw sub-committee meetings, conducted workshops and public hearings, and drafted the HMP, itself, per the recommendations of the HMP planning committee of each community. Without these services towns would have been burdened with hiring outside consultants, or, utilizing in-house planners, most of whom were not experienced in coastal issues.

The detailed planning methodology utilized by the advisors followed standard practices as outlined in Figure 1. Although the advisors provided important technical assistance and maintained the focus and motivation of each town, the predominant aspect of the harbor planning process was to ensure as much public participation and input into the development of the plan as possible. The membership of planning committees deliberately included a scope of individuals with specific vested interests in the issues being discussed and drafted into the HMP. If consensus on issues, goals and policies could be reached by a diverse group, it was anticipated that the general public, as well as city and town officials, would recognize the program as balanced and beneficial to the local community. To a large extent this logic was supported by the vote of council members to approve the HMPs and by the minimal amount of changes necessary based on suggestions at the final public hearings. However, there were groups that felt the entire process never implemented any of their proposals and they have fought to prevent the implementation of the plans.[4]

Harbor Management Planning Issues

Although each town had unique qualities that required specific attention, a number of common issues were identified during the planning process. Those that received the most attention during workshops, public hearings and committee sessions were: 1) water quality; 2) enforcement of existing rules and regulations pertaining to boating safety, commercial fishing, waterfront zoning, moorings and other water-related activities; 3) public access to the shoreline; 4) water-dependent uses; 5) concerns of waterfront property owners, known as littoral and riparian rights; and 6) growth of recreational boating. The complexity of each issue varied from town to town, but there were sufficient similarities to classify them as

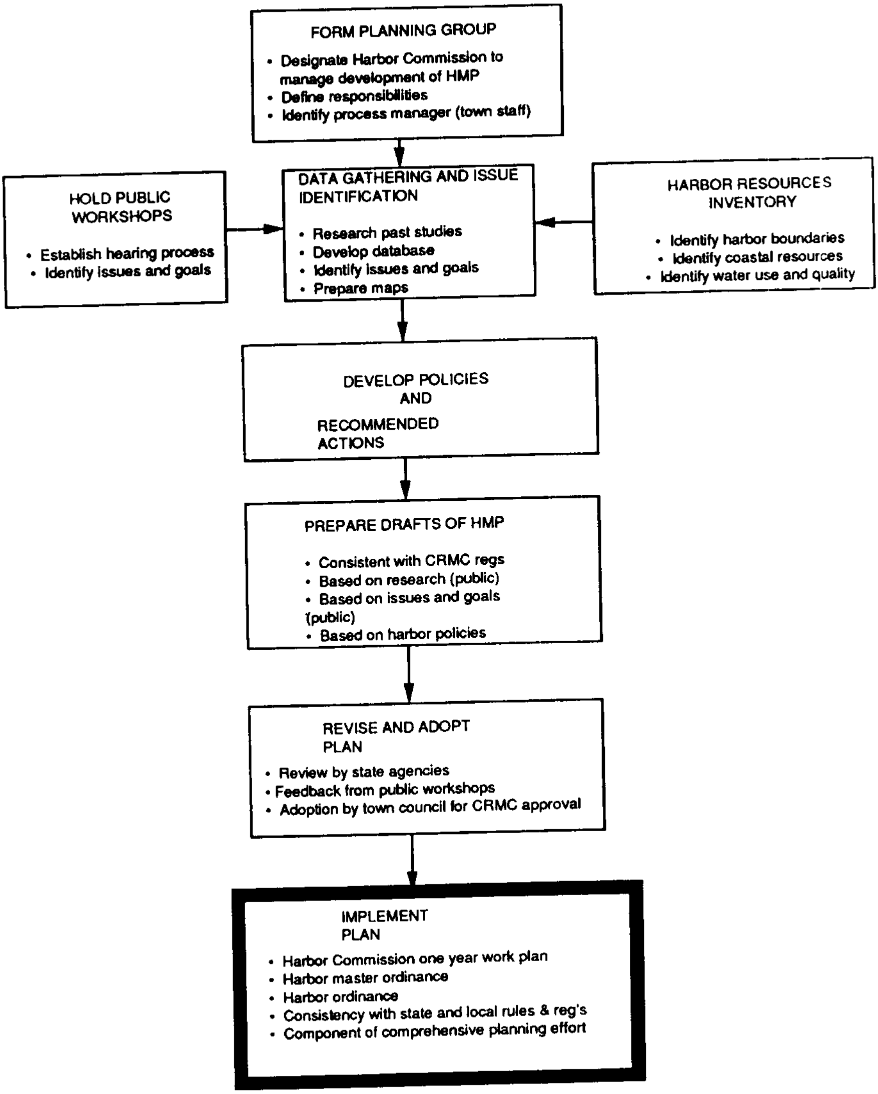

Figure 1. Municipal harbor management planning process

fundamental categories that should be addressed by any community drafting a harbor management plan.[5]

Water quality led the field as the issue of greatest concern to the most people. Every community placed the preservation and improvement of the condition of the waters under the control of their town as the number one issue. In many cases, water quality was also directly impacted by the other issues. Boating, waterfront development, activities conducted by riparian property owners, access sights, and the degree of enforcement of numerous rules, regulations and laws pertaining to the entire range of coastal issues, all have a bearing on local water quality. So, from a practical perspective, each HMP dealt with devising management techniques, enforcement mechanisms and educational tools that could effectively coordinate multiple water-related activities without disturbing water quality.

Initial Results of HMP Efforts

The challenge to develop HMPs that result in well managed harbors and shorelines is not easily met. Because waterfronts are populated with so many factional organizations, each having their own approach to harbor management, minority views of the consensus decisions limit the overall success of local HMPs. Ordinances required to implement sections of the plan may not be adopted, thereby reducing the effectiveness and enforceability of the HMP. However, in spite of this shortcoming, the Rhode Island HMP process has proven to be a major achievement.

Local harbor management issues were brought to the attention of the public, and more importantly, to municipal officials. The public forum helped to identify jurisdictional overlaps, regulatory enforcement problems and weaknesses in the water quality management program. It also highlighted the acute lack of education, awareness and understanding that exists among waterfront decision-makers concerning the interrelationships between water-borne and shoreside activities. Finally, working through the HMP process at the local level has given coastal communities an appreciation for the need to have informed, respected and effective waterfront officials to manage this expanding arena of responsibility.

HARBORMASTER TRAINING

Municipal governments throughout the country are under pressure to conduct effective waterfront management programs for the multiple uses that have become common along their shores. In order to achieve this goal and to deal with the numerous conflicts resulting from the diversity of coastal uses, many states have given local communities the power to design and implement rules and regulations for the efficient management of their waterways. In doing so, towns have re-evaluated their current management policies and practices, and have often revised them. These changes have created the need for qualified harbor managers to participate on the design and implementation team for new policies which regulate recreational boaters, commercial fishermen, marina operators and waterfront residents. These managers must ensure that the rules and regulations are properly enforced and that assistance is provided to all users of their waterways. In traditional terms, this harbor manger has been, and continues to be the local harbormaster.

Today these public servants frequently find themselves at the center of complex management issues and many of them are unprepared to deal with the increasing conflicts their position encounters. They have been expected to properly manage and control the waterfront without being provided with the skills needed to accomplish the task. In order to meet their broad responsibilities ideal harbormasters should have degrees in law, business management, accounting and marine affairs. They should be trained in medical emergencies, pollution control, law enforcement and marina operations, while also being experienced sailors and navigators with intimate knowledge of local waters. Achieving this level of accomplishments would be an extraordinary task, yet having a base knowledge in these areas is a reasonable goal.

It is important to emphasize that the increase in coastal activities requiring the presence, interaction or involvement of the local harbormaster has made the position of harbormaster a full-time effort in most cities and towns. Recognizing this situation as factual and coupling it with the responsibilities being placed or shifted onto the shoulders of the local harbormaster as listed above, it is evident that for someone to function effectively in this capacity, that individual must be familiar with a great deal of information.

Development of Harbormaster Training Program

As harbormasters begin to receive more recognition, they will also be expected to meet certain standards of performance. For many years the stereotypical image of a northeastern harbormaster was of an old crusty sailor or fishermen who either inherited the position because it was a family tradition, or was the recipient of a political favor. In most cases, little, if any, compensation was provided, and the harbormaster provided minimal services in return. Of course, in practice this image varied substantially and a number of communities have been operating what can best be described as a professional harbormaster's office for a long time. Unfortunately, the perception of boaters, public officials and the general public, was that most harbormasters fell into the stereotyped categories. There is, however, a growing presence of a new type of harbormaster in certain harbors around New England. These harbormasters have professional training and are experienced, multi-talented individuals, located most often in harbors with budgets substantial enough to hire the best person for the job.

In order to alleviate some of the pressures currently facing harbormasters and because all towns deserve and require the services of well-trained personnel, the University of Rhode Island Coastal Resources Center (CRC), in conjunction with the Rhode Island Harbormasters Association, embarked on a task to develop a training program specifically for harbormasters. Based on information gathered through the harbor planning process, particularly the fact that issues involving the average harbormaster were becoming more diverse and complex, as well as first-hand experiences of the author, a study was undertaken to quantify the experience, training, expanding duties and educational needs of harbormasters in New England.[6] A survey of harbormasters in New England conducted by the Rhode Island Marine Advisory Service in 1989 clearly supported the hypothesis that the responsibilities of harbormasters were increasing, without a corresponding increase

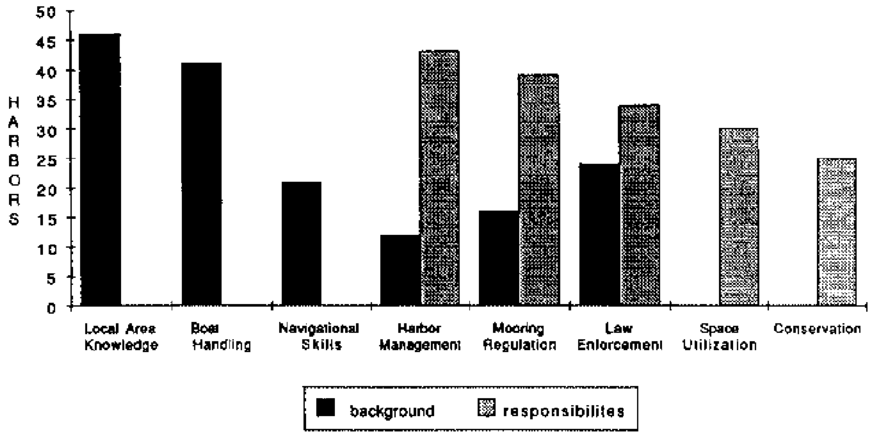

Figure 2. Experience v. responsibilities

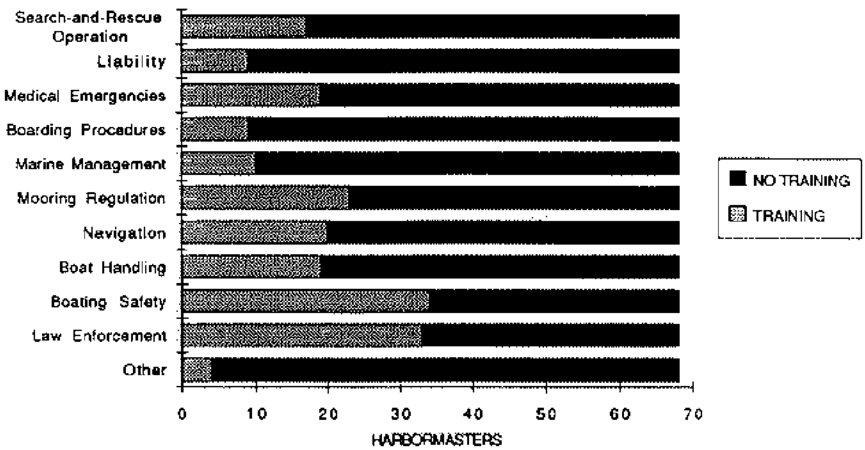

Figure 3. Training received

in training or education in the new fields (Figures 2 & 3). Most importantly, the survey indicated that more than 71% of the respondents wanted additional training.[7] This information demonstrated a clear mandate for the development of a basic training program for harbormasters.

Format and Content of the Training Program

The survey results were supplemented by field visits with harbormasters throughout New England in order to gain sufficient background information for a training curricula. These visits offered a close-up look at habormasters on-the-job, helped to pin-point specific training topics and issues, and gave program developers a broader perspective of the range responsibilities and status of New England harbormasters. Eight issues were considered important by the harbormasters and they comprise the program curriculum. These are: medical emergencies; liability issues (specifically in regards to moorings and towing vessels); boating safety, boardings and inspections; seamanship; administrative law enforcement procedures; harbor management (multi-use issues, conflict resolution); mooring technology, regulations and management; and pollution control. Basic training in these eight areas was designed to help harbormasters become more productive and efficient, but most importantly to improve their ability to assist the users of local coastal waters.

With funding provided by the Rhode Island Sea Grant Program, the Coastal Resources Center and the Rhode Island Harbormasters Association proposed to conduct a pilot program for Rhode Island harbormasters and their assistants. Because many harbormaster positions are seasonal, the decision was made to administer the pilot project on weekends during the off-season, between the months of November and March. The first test of the program was scheduled for November 1990, with program review and revisions conducted during the winter and a second test to be held in March 1991.

Due to the significant amount of the information that needed to be presented a 40 hour program of instruction was selected. This would double the amount of training that had been received by most of the better trained survey respondents[8] and be a major step in the creation of a better informed group of waterfront officials. A University of Rhode Island conference room overlooking Narragansett Bay was chosen as the sight for classroom-type sessions and a near-by harbor was the venue for on-the-water exercises and demonstrations. Another aspect important to the overall success of the program was the selection of the faculty. Several well-known local experts in marine law, boating safety, and law enforcement training were recruited and combined with American Red Cross, marine industry and consulting professionals they formed a respected and dedicated group of instructors.

The initial schedule arrangements were made based upon input from the Rhode Island harbormasters who were scheduled to participate in the November test course. The first session was taught over four Saturdays and then modified based on feedback from the students and staff. The March 1991 program was reformatted to be taught on six weekday evenings and two Saturdays. Subsequent courses, which will include out-of-state students, may be taught over two full weekends, or five consecutive days.

In order for the program to achieve the desired level of professional acceptance, CRC and the Harbormasters Association sought official endorsements from the University of Rhode Island, United States Coast Guard, and Rhode Island Department of Environmental Management-Division of Boating Safety. Each of these agencies played an important role in the implementation of the training program and, by incorporating their expertise, the program gained substantial professional backing and credibility among the harbormasters and town officials. It was also important to provide program graduates with official recognition of their accomplishments. The College of Continuing Education of the University of Rhode Island formally reviewed and adopted the program and authorized the issuance of certificates in "Basic Training for Harbormasters" as well as four continuing education credits for the graduates. This will also enhance program credibility and form a baseline measurement tool for evaluating the future qualifications of harbormasters.

Initial Results and Feedback

The November 1990 class consisted of eleven students, all harbormasters or assistant harbormasters from seven of the twenty-two cities and towns in Rhode Island that have harbormasters.[9] As is typical and useful to program developers everywhere, students were given an evaluation form to complete at the end of each program section and at the conclusion of the entire course. They were asked to assess the performance of each instructor, the importance of the session topic and some ancillary questions. Response was unanimous that the course will help them to be better harbormasters. Strengths and weaknesses were identified among faculty, presentation style, session content, and program format. In some instances there was considerable disagreement among the students about certain aspects of each module. This divergence appears to be related to experience. The less experienced harbormasters tended to find the information more useful and beneficial than their more experienced colleagues. Changes were made based on these detailed evaluations and are being implemented during the second program.

The best measurement of the success of the initial training was the registration of sixteen students from an additional six communities for the March 1991 class. When this group completes the course nearly 60% of the waterfront communities of Rhode Island will have trained harbormasters and sufficient information will be available to regionalize the program. Another indication of the positive impact of the course has been the steady stream of inquiries being received about the program from prospective students throughout southeastern New England. A course description was distributed by the Rhode Island Harbormasters Association at the Rhode Island Boat Show in January 1991 and this small public relations effort has given a regional perspective to the program. Finally, it is significant that every student and every inquiring caller has displayed a high degree of willingness to pay a substantial fee to attend the course. This factor will be included into the planning process of future sessions.

HARBORS EDUCATION PROGRAM

A second critical component of the educational package identified during the harbor management planning process was the training of local decision-makers involved with water-related issues. The need for municipal level education is easy to understand given some of the developments along the Rhode Island shore. Changes in the attitudes of society, evolutionary processes in business and industry, and the effects of nature have altered the physical appearance of Rhode Island ports and harbors and helped to spur modification of shoreside activities in their immediate vicinity. Within the harbors and waterway systems throughout Rhode Island, the affects of technology and increased personal leisure time on the environment are easy to identify.

In a state in which no resident resides more than 25 miles from the shore, the trend toward development of Rhode Island coastal towns has been dramatic. Some communities had a population increase of nearly 70% between 1970 and 1980[10] and new housing in coastal rural towns increased 37% between 1980 and 1985.[11] These demographic shifts have resulted in legitimate concerns about the effectiveness of municipal sewage treatment plants, and the high levels of demand for the use of the coastal waters and lands. Rhode Island beaches are used by 65% of the residents of the state, nearly half of the citizens spend time on one of the more than 50,000 sail and power boats that operate on state waters, and 25% of the populace enjoys fishing.[12] With numbers like these it is easy to see how the Statewide Planning Program believes that "the coastal areas of Rhode Island are probably under greater development pressures than any other area of the state."

As mentioned earlier, the period of accelerated development that occurred in Rhode Island during the early 1980s heightened public awareness of several coastal issues. Many individuals, if not most of the users of the small bays, harbors, and ports of Rhode Island, began to realize that the expansion of recreational boating and fishing, the concerns of commercial fishermen, public demands for safe, clean swimming areas, the ability of the public to access the shoreline, the preservation of high water quality standards and many other water-related activities and issues were not receiving the benefits of planning. The high demand for waterfront property and the divergent uses of the shorefront and the water itself were and still are the basis for numerous conflicts between users.

Development of the Harbors Education Program (HEP)

In order to safeguard and improve the water quality of our harbors, the living resources within the harbor waters, and the diversity of recreational, commercial and industrial uses that occur on, in, and adjacent to the harbors, the Rhode Island Sea Grant Program and The University of Rhode Island Cooperative Extension

Service (CES) began the development of an educational program. Original plans were to develop a program that would be a large public education exercise that would inform as many people as possible about the issues of coastal and harbor management. After lengthy discussion and committee review,[13] the decision was made to design a program specifically for elected, appointed and volunteer government officials serving on various municipal boards, committees and commissions. These individuals traditionally make many of the decisions and policies which impact harbor life and activities, yet, most of them have little understanding of the water-side consequences of their decisions. By aiming the educational effort at these persons the program will be able take another step forward in the process of modifying societal behavior and perceptions as they pertain to the management of the marine environment and related ecosystems.

The program goal is "to conduct a training program in which a select group of local and town officials will learn about the complexities of Rhode Island Harbors, their multiple uses, and techniques for managing them."

Program Format and Products

The development of the Harbors Education Program has focused on presentation style and format. Because course content was identified during the HMP process, it has been important to match the best instructional techniques to the issues. The program must be attractive to people who are already very busy being volunteers and municipal officials that routinely attend weeknight meetings. HEP has to incorporate unique features not readily available to the average person, while being an entertaining educational experience. A Rhode Island CES Wildlife Environment Program, conducted during the late 1970s, has served as a model for the development of HEP. The CES program screened applicants for admission, utilized multiple site locations, took place on weekends, and recruited high caliber instructors. Similar criteria were proposed for HEP.

At this point in time, the most important programming decision has been to use the harbors themselves as classrooms in which to demonstrate the complexity of harbor and coastal management issues. It is much easier to recognize multiple use conflicts and environmental impacts in the field, on the water, or walking the shoreline, than from a remote location. Class size was also considered a restricting factor in the overall effectiveness of the program. It is important for participants to be able to interact with faculty in order to achieve the desired level of competence and understanding about the issues. Therefore a class size of no more than 25 has been chosen and this is also expected to increase the competition for admittance into the program. Session formats, both in the classroom and in the field will include:

1. hands on activities, such as using a bullrake to dig quahogs;
2. solo and/or team experience to "feel the harbor," focus on problem awareness, issue identification, individual perceptions and appreciation of the harbor;

3. use of unique venues to get a sense of place and function, a tugboat, historic home, marina, sewage treatment plant, and museum;
4. problem solving;
5. role playing; and
6. standard lecture and AV presentations;

Two approaches were being considered for the first session of HEP in the fall of 1991. The first method concentrates on one community, its decision-makers and waterfront and it restricts attendance to locals. The second option takes selected applicants from throughout the state to four different harbor areas. Benefits of the single town approach include reduced logistical problems and a concentrated learning experience for town officials on site specific harbor and coastal management issues. The ultimate aim is to put this training into use by making better decisions. On the negative side, it may not be possible for a sufficient number of municipal board and commission members from one community to attend the program. This impacts the cost-effectiveness of the program both financially and from a decision-making perspective.

The multiple harbor plan has good and bad points as well. On the positive side, HEP would gain greater exposure throughout the state, and individuals in diverse coastal cities and towns would have a better understanding of generic harbor management issues. This approach stimulates the development of a new network of contacts with people from all over the state that are interested in the same issues. However, participants would then be tasked with taking their new knowledge back home to educate local colleagues, and it is not as likely that one or two persons from one or two municipal committees of a single town can make the same type of impact as a large group. Program arrangements for multiple sites are also much more complex. There is equal interest among program developers and advisory personnel for both choices and the possibility of running two pilot programs is under discussion. In either case, approximately 30-35 hours of instruction will be given.

A small number of program students will be chosen to document the program on film for use in a "harbor and coastal issues awareness" slide and/or video presentation. In this manner it will be easier to expand the knowledge base about Rhode Island harbors by having an educational tool available for civic organizations, schools, town officials and others that may not be able to participate directly in HEP.

Program Status

Although HEP has received a limited amount of financial support from outside of Sea Grant and CES, it has been designed in such a manner that it can be conducted with a minimal budget. Program attractiveness, however, is directly related to the amount of available resources, and therefore efforts are continuing to locate additional funding. Town managers, planners and various board members from around the state have been solicited to assess local interest in the program.

There has been unanimous agreement by every contact that the program would be beneficial to their community and should take place as scheduled, and there have been a few indications that several municipalities may be able to pay a fee if the single site option is selected for their community. Prospective faculty, including a member of the Rhode Island congressional delegation, are eager to participate and the program is on track for a successful debut in the fall of 1991.

CONCLUSION

The processes and programs outlined in this paper are simple, easy to implement techniques that allow ordinary citizens and key local officials to become more involved with the coastal and harbor issues of their communities. Developing a HMP, becoming a better trained harbormaster, or viewing your town from a boat for the first time can result in lasting impressions of the symbiotic relationship that must exist between on-the-water activities and the utilization of adjacent waterfront property. Achieving this level of understanding will take time and constant pressure from concerned individuals in civic organizations and at every level of government.

The Rhode Island Harbors Management Project, Basic Training for Harbormasters and the Harbors Education Program have provided new impetus for the coastal communities of the state to realize that the well-being of the waters adjacent to their shores is, to a great extent, under their control. Most town governments had never given this careful thought, as civic management issues had always been land-based. Now people are beginning to see the relationship between land-side activities and the impacts they have on the coastal environment. Likewise, the increase of waterborne recreational pursuits, and changing character of the commercial waterfront has generated an interest in effective management of critical and finite coastal resources. As we move towards the new century, proactive involvement by responsible state agencies and affiliated university service organizations has enabled Rhode Island to set a new standard for harbor planning and waterfront management training in New England.

ACKNOWLEDGEMENTS

The author wishes to express his thanks to his colleagues on the Rhode Island Harbors Management Project Team for all their work and support of the project: Tim Dillingham, CRMC; Jeff Willis, CRMC; Virgina Lee, CRC; and Pamela Pogne, CRC. Special appreciation is extended to Mark Amaral for his diligence in overseeing all the details of the harbormaster training and doing much of the research that indicated the need for the program. The author also wishes to thank David Abedon for his assistance in developing a Harbors Education Program for Rhode Island.

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Coastal Ocean Space Research and Utilization in the Middle East

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ABSTRACT

Egypt, Israel, and the United States are conducting a cooperative program of aquatic technologies under the auspices mainly of the U.S. Agency for International Development (USAID). The program, which began in 1980, has encompassed a dozen projects in over 20 laboratories in the three countries. They include fisheries and aquaculture, shore processes, lakes management, climate prediction, seafood toxins, waste water recycling and primary productivity of the Eastern Mediterranean Sea. The Program is designed and coordinated by a steering committee which includes representatives from the Egyptian Academy of Scientific Research and Technology, the Israeli Institute for Oceanographic and Limnological Research, Texas A&M University, and the New Jersey Marine Sciences Consortium.

BACKGROUND

Throughout history, man viewed the ocean — when he thought about it at all — as an infinitely broad highway on which to transport people and things; as a source of food; and, depending on the viewer's perspective, as a protective shield or exciting battle zone.

For the past three decades, however, the world's peoples have become increasingly sensitized to our surrounding seas through two additional major issues:

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1. Whether recovery of the ocean's mineral resources is economically feasible; and

2. Whether the ocean's capacity as a garbage can is really unlimited.

Still more recently, a new concept has been introduced to peoples in certain parts of the world, i.e. use of the ocean, particularly its coastal regions, as a persuasive instrument for peaceful cooperation.

Typically, it was President Harry S. Truman who observed that nations working together were less likely to be attacking one another. At the time, he was referring to the possibility of persuading Israel and her Arab neighbors to cooperate on some major engineering projects of potential mutual gain.

It took three decades to translate those thoughts into deeds. Then, in September, 1978, the United States Congress passed, and the President signed, the International Security Assistance Act of 1978, PL94-224, amending the Foreign Assistance Act of 1961. This legislation included, for the first time, establishment of a program and fund for Regional Cooperation in the Middle East (Section 48 (C) (5)). It became known as the "Regional Fund" and was directed to cooperative projects between Israel and her neighbors. Responsibility for the Program's implementation was assigned to the United States Agency for International Development (USAID).

During the period between October 1978 and August 1980, a small group of American, Egyptian, and Israel oceanographers and coastal engineers, working together very informally, developed a series of projects in science and technology which became known as "The Cooperative Marine Technology Program for the Middle East." The program was officially accepted by the United States Agency for International Development (USAID) on August 23, 1980, as the first enterprise endorsed under the Regional Fund's auspices. Actually, on that date a group composed of a dozen scientists each from Israel, Egypt, and the United States was quietly conducting an historic meeting in San Diego.

The rest of this story must be played out against a backdrop composed of a strange sector of the world's Coastal Ocean. It is strange because in all likelihood there is no other region where the effect of man's activities has been quite so dramatic.

THE MIDDLE EAST ENVIRONMENT

To understand this, it is necessary to consider the nearly enclosed nature of the Mediterranean Sea. The characteristic hot dry winds blowing from the Sahara cause excessive evaporation, leaving water whose salinity and density is about 10% higher than that of the Atlantic. The condition at the shallow Straits of Gibraltar, therefore, is one of a thin layer of light Atlantic water flowing inward, overlaying the heavier Mediterranean water which flows outward, cascading down to its natural sigma-T level on the Atlantic side, i.e. about 800 meters.

Inasmuch as photosynthetic activity reduces the nutrient content of the surface layer practically to zero, the result is continual impoverishment of Mediterranean waters, to a nutrient concentration level of about 10% of Atlantic waters.

The effect on the biological food chain is predictable; fishing is very poor. In actuality, nearly all of the nutrients (i.e., Nitrate, Phosphate, Silicate, etc.) in the Southeast Mediterranean originated in the Nile River. Thus, the effect of the Aswan Dam on Mediterranean fisheries was predictably negative.

The second effect refers particularly to the coastal ocean sector. Historically — i.e. in geologic time — the position of Egypt's Mediterranean Coast represented an equilibrium reached eons ago, between the provision of sediment by the Nile and erosive annexation of the sediment by the Mediterranean.

The estimated 160 million tons of sediment trapped annually by the Aswan Dam has given Egypt the most drastically eroding coastline in the world. An estimated third of a kilometer disappears into the ocean every year in the most seriously affected areas. Obviously, this must be a highly variable situation, depending on the wave climate, topography, and several additional factors.

The problem's origin relates to the nearly one billion cubic meters of sediment which are transported annually from the Nile delta to the east, near Haifa.

A numerical model of the sand budget along the coast is requisite to predicting the sediment transport. In turn, input of the parameters of waves, current, and wind are essential to the model's development. Data for the model are collected at Haifa and Ashkelon in Israel and Ras-el-Bar and Abou-Qir in Egypt.

The Egyptians and Israelis are currently working on the difficult problem of developing a wave climate in the deep waters. This is accomplished by making backward refracting calculations toward the deep water. This enables the forward calculation. These theoretical results are then compared with real field data, also obtained under the cooperative program. Agreement closes the loop; lack of agreement indicates a need for further recalculation.

The Egyptian Coastal Research Institute began collecting relevant data since the early 1970s, using primitive equipment. In 1980 (with the initiation of the Cooperative Marine Technology Program for the Middle East), they began using the CAS system developed at the Scripps Institution of Oceanography, collaborating in the project. This allowed them to analyze the wave spectrum during the decade of the 1980s. They worked on developing a predictive model in collaboration with Dr. D. Inman and his staff at the Scripps Institution. At the same time, the Israeli participants were developing a numerical model using a different approach and different formulas. This gave them all very valuable hands-on experience.

Hydrographic surveys are conducted in the fall and spring annually. Together, concentrated profiles have been made around "sensitive" places, e.g. Rosetta, Burrulus and Bard-a-wil.

Wave spectra were fashioned during the first and third phases of the project. This was a time-consuming effort which has since been replaced by a system that depends on sensors, i.e. data logging.

Enormous amounts of CAS wave data have been obtained near Ras El-Bar and Abou Qir and subjected to the numerical modeling. Also wave roses have been constructed on monthly bases.

Actually, the Nile Delta began to erode due to the construction of dams and other regulators, as a result of sand and mud storage behind these structures, as far back as 1900. The erosion became much more pronounced after 1964 with construction of the Aswan High Dam. Off Ras El-Bar erosion has been estimated to be about 2 km during the last 10 years.

The littoral currents have been measured on both sides of the following regions: Rosetta, Burrulus, Ras El-Bar, El-Arish and Bard-a-Wil. The predominant current is from west to east. Currents have been measured beyond the breaker zone at depths of up to 6 meters only.

General current patterns at the surface and along the bottom have been analyzed using Eigen-functions. These methods, incidentally, are not predictive, but statistical in nature. Another method of analyzing the data is by using the T-S diagram. A third method is to calculate erosion and accretion, deriving, thereby, the net sediment transport.

A number of protective measures off Edku, Rosetta, Burrulus and Ras-El-Bar have already been taken as a result of the project's findings, and this has been the major payoff of the project, to date.

Dr. Naeeum Anwar, a newly recruited Professor in the Faculty of Engineering of Alexandria University, has considerably advanced numerical modeling of sediment transport and simulation of bathymetric changes. He has constructed several models dealing with sediment transport and completed a schematic representation of a grid using the wave diffraction method. He is assessing various methods of computing sediment transport and has already prepared a mathematical model illustrating this transport. The results of the shallow wave height and direction measurements at Ras El Bar and Abou Qir, obtained in October 1988, have now been published. Variations of contour lines at Rosetta have been determined using the numerical model.

Dr. Iosilevsky, who has joined the IOLR in Israel, in contributing to the research effort by writing a computer program for wave processing data (using the data from CAS). This program is in two packages. The first is for reading the data, correcting errors and then preparing for the spectral analysis of the data collected. The second package is the spectral analysis itself.

Since the program "which was written a long time ago" suffered from some equipment malfunctions, the Egyptians and Israelis are now reconciling methods of observations and data analyses in order to ensure homogeneity of findings and conclusions.

State-of-the-art technology is not equal to the task of preventing nature's incursion, i.e. to stopping erosion. Accordingly, beyond the abovementioned protective measures, the Egyptians' and Israelis' primary objectives are to develop the means of predicting the nature and degree of damage, as a necessary ingredient of coastal planning. They have almost completed the set of computer programs which will predict the efficiency and durability of structures planted at or near the shoreline.

A use of coastal ocean space which I've never heard mentioned outside of our Program relates to the possibility of a correlation between the atmosphere-ocean energy interchange and rainfall. The Israelis and Egyptians are currently collaborating with Princeton University to explore the validity of the postulate that knowledge of this exchange can be used to forecast rainfall on a climatological basis, i.e. over several seasons. In the Mediterranean Sea, evaporation exceeds precipitation and river runoff, causing an Atlantic water surface inflow through the Straits of Gibraltar and an outflow near the bottom.

Recent studies show an associated sea-level drop from the Atlantic to the Mediterranean of about 0.15 m. Such a drop is not steady but varies seasonally. The seasonal variation in the sea-level seems to be associated with different exchange states at the straits.

As the exchange states could be related to the deep water formation process in the Western Mediterranean Sea, efforts will be undertaken to gain insight to these processes. Needless to say, this experiment requires detailed temperature data. The participating scientists feel that they're close to establishing the correlation to the point of ability to make fairly well informed guesses of expected rainfall, for perhaps a year in advance. If the concept proves workable, it will create obvious benefits for both agricultural and urban planning.

The last step may be more in the realm of fancy. The Israeli engineer who originated the project suggests that if the correlation proves to be effective, it might then be possible to increase the "storm effect," i.e. rainfall, by lowering the sea surface temperature of the Southeastern Mediterranean. Perhaps you would agree that this would be a most unusual utilization of coastal ocean space.

What has been described above is essentially a quid pro quo arrangement between man and nature. The Aswan High Dam has given Egypt an incalculable bounty of energy and conserved water resources. In retrospect it might have been possible to achieve all this without consequent damage to fisheries and the coast. Even the Monday morning quarterbacks cannot offer cogent opinions on the subject.

We now turn to an aspect of Coastal Ocean Space whose utilization is aesthetic rather than materialistic but which is no less important for being so. This refers to the famous coral reef of the Red Sea. At the roof of the Red Sea lies the Gulf of Aqaba. Its semi enclosed nature and linkage to the warm Red Sea waters enable the farthest north coral development in the world. This gulf is the scene of highly complicated coastal ocean planning owing to the requirement to provide recreation, mariculture, and maritime commerce simultaneously.

But this is supposed to be the story of the Mediterranean; the Red Sea story must wait for COSU III.

SOCIOLOGICAL AND ECONOMIC ACHIEVEMENTS

The Program just described differs significantly from conventional USAID Programs in that social progress (i.e. cooperation between Arab and Israeli scientists and institutions) is considered to be at least as important as their economic and intellectual accomplishments. A few highlights of cooperation may serve to demonstrate the Program's objectives.

The Egyptians and Israelis have conducted, to date, twenty-two planning and reporting conferences, mainly in Cairo and Alexandria to begin with, but now, increasingly in Haifa and Elat. A full scale workshop is held each year in which all of the project Principal Investigators participate. With a few exceptions, American participation has been limited to the Program's coordinators. Planning and operating procedures are being developed increasingly by representatives of the Israeli and Egyptian Institutions vis-a-vis their American colleagues. The most recent annual workshops were held in Washington, DC in May 1990 and Suez, Egypt and Haifa, Israel in August 1990.

At this point in time, 50 Israeli person-trips have been made to Egyptian laboratories where the scientists have cooperated in the research, and have assisted in classrooms and with graduate students. The initial visits to Israel by the Egyptian Under Secretary of State for Aquaculture and Director of the Egyptian Coastal Protection Institute produced dramatic results. The latter, for instance, was appointed a consultant to the Israeli Government in 1987. Sizeable Egyptian delegations now routinely attend the workshops held in Israel, and Egyptian scientists visit Israeli laboratories as scientists in residence.

The shore processes project has from the beginning, fostered joint training of the Egyptian and Israeli engineers at the Scripps Institution of Oceanography. Such joint indoctrination is especially important in this project, because of the requirement for precisely aligned data from the offshore sensors monitored by the two countries respectively.

Twenty doctors' and masters' degrees have been obtained under the Program's auspices, and the projects have resulted in over fifty papers. The Primary Productivity, Waste Water Utilization, Management, and Shore Processes Projects, have produced the first coauthored publications. Perhaps the highlight of the Program, to date, occurred during September, 1983, when Dr. A. R. Bayoumi and Admiral Yohay Ben Nun (original Egyptian and Israeli coordinators respectively) were honored for their contributions to the Program by being designated as the first co-recipients of the International Compass Award given by the Marine Technology Society for distinguished service in international marine affairs. In August, 1985, Dr. El-Sayed received the Distinguished Service Award from the American Institute of Biological Sciences, for his role in developing the Program.

In summary, social gains seem to be self catalyzing and progress to be exponential. Closer working relationships lead to better results. Better results awaken interest by scientists outside the program. The consequently improved recruiting opportunity offers more selectivity and more competent participation to the coordinators. Increasing competence leads to closer working relationships, better results, etc. In effect, the social machinery appears to be fueled by its own achievements.

PROGRAM MANAGEMENT

More than any other aspect of the Program, the Steering Committee reflects the spirit of cooperation so central to the Program's success. The Committee's functions include, inter alia:

a. Stimulate thought towards project initiation in the participating countries;
b. Assist prospective principal investigators in preparing their projects, including identifying partners in the other countries;
c. Facilitate communications among the prospective partners;
d. Screen the projects at first and second levels (this normally involves reducing 20 to 30 proposals to a package of between 5 and 8);
e. Prepare the final proposal package, including management. Proposals are generally prepared at approximately two year intervals;
f. Negotiate with the Agency for International Development;
g. Meet periodically with the principal investigators to assess progress and assist in the administrative phases;
h. Meet with senior officials in the three participating countries to brief them on the nature and activities of the program; and,
i. Prepare the final technical reports to be submitted each year.

In retrospect, the reasons for the effectiveness of the Steering Committee are not obvious. The simplest answer relates to the personalities, particularly of the Middle Easterners. Except for their individual charm, dedication, courage, and exceptional intelligence, the Egyptian and Israeli coordinators, Drs. A. M. Eisawy and Y. Cohen, respectively, are quite dissimilar. Yet they are willing and able to come to agreement on issues and priorities with extraordinary alacrity. Further, since each enjoys a relatively high position and the complete confidence of his superior — who is at the ministerial level — they are able to penetrate, and affect, national policy.

The Committee obeys no set rules; procedures are set ad hoc, by consensus. We often expand membership temporarily as additional or special expertise is needed. For instance, the chief financial officers of the Egyptian Academy and Israeli Institute attend most meetings, since budget and finance are perennial issues of moment.

REPORTS AND REACTIONS

On June, 1982, the group submitted its first annual report to USAID. Outlined therein were relatively detailed accounts of both technological and sociological progress achieved during the reporting period. Since then five more such reports have been submitted. Owing to the manner in which steering committee meetings and workshops dominated the program's planning process, progress reports were submitted immediately following each such meeting. They served the dual advantages of faithful reporting and documenting the program's progress, and keeping the sponsor informed in real time. More recently, with imposition of AID's new reporting requirements, progress reports must be submitted semiannually. This converts the documentation of the Program to a sterile pattern and reduces effectiveness, but it does provide a more rigid adherence to "procedure."

One of the most heartening aspects of the Program's conduct has been the demonstrated high level support. In Egypt, the Deputy Prime Minister, Yousef Walli, has been particularly outspoken in his support for intensified cooperation between the two nations, generally, with particular reference to the Program. The Egyptian Minister of Science, Adel Ez, and the President of the Egyptian Academy of Scientific Research and Technology, Dr. A. A. Abdel-Latif have expressed the strongest possible support for the Program. In Israel, both Prime Minister Yitzak Shamir and Shimon Peres have expressed their support for the Program, with M. Peres displaying special enthusiasm for the principle. The U.S. Ambassadors to the Middle Eastern countries are unanimous in their praise for the Program which increases its effectiveness cybernetically.

In the United States support has been generated within the Congress, particularly within the Senate Foreign Relations Committee and the House Committee on Foreign Affairs. Senator Claiborne Pell and Representatives James Scheuer and Henry Waxman are particularly outspoken advocates. It must be emphasized, in this regard, that the Regional Cooperation Program was spawned by the legislative process. It is conceived, inspired, and fostered by the Congress. The U.S. Agency for International Development (AID) is charged by the Congress with responsibility for the Program's implementation. In originating the Program, a group of farsighted Senators and Representatives essentially asked the question: "In an era when the USA gives $5 billion/year to Israel and Egypt, a large portion of which goes for munitions, what's wrong with allocating 0.1% of that sum to encourage those countries to cooperate in their quest for food and water resources, health benefits, and general economic improvement?"

Sometimes, Congressional interest can be overdone. Two years, ago, a Representative sub-earmarked 20% of the ($5 million) funds for a "pet foundation," via a single apparently innocuous sentence in the Appropriations Act. In a semiautomatic gesture USAID simply transferred the funds from the first Program which came up for renewal. It happened to be the Marine Program. Consequent premature termination of this Program was prevented only by the personal efforts of Representative James Scheuer (D-NY), who, with considerable collaboration from his colleagues, lobbied strenuously for the Program's revivification in both Houses.

In the following year I was asked whether I would like funds to be earmarked to the Marine Program. The offer was declined on the basis that the quality of overall Regional Cooperation will decline if the implementing agency (which, for whatever reason, never appeared much opposed to the earmarking) is not permitted project selection authority.

Viewed as objectively as possible, Congressional oversight appears to be supportive, far sighted, and (except for the previously related instance) non-interfering. The individuals and committees most responsible for policy in this area last year increased the appropriation by 40% over the previous $5 million annual level, to $7 million.

Another management question relates to just how fast and far a technology like Ocean Space Utilization can be pushed in the Middle East. The present consensus is that all of the money that is being spent in the Program at the present time is truly in the Program's best interest. Further expansion, however, depends on the Program's attractiveness to excellent ocean scientists and engineers in Egypt and Israel (and now in neighboring states). The question may be asked: "Are there enough competent scientists and engineers in the cooperating Middle East countries who are really interested in joining this Program and who would subscribe wholeheartedly to its fundamental tenets of useful cooperative endeavor?" At this point in time, the candid answer is probably "few, but growing fast!"

A crucial third issue, however, relates to the younger folks. We can't help but wonder whether all of us are making the strongest possible effort under the circumstances, to search for, identify, and recruit willing and competent graduate students into this Program. The success of our Program must lie with this next generation which will hopefully possess fewer social biases. While the cadre of eminent scientists who have chosen to devote their careers to peace in the Middle East is, of course, the sine qua non of our Program, without whom we could never have gotten started, expansion to a recognizable regional effort will rest with the next generation, i.e. the younger scientists.

The fourth issue concerns the relative effectiveness (towards the Program's fundamental goals) of an individual COSU-Type Project vs. the current packaged Program. The "Cooperative Marine Technology Program for the Middle East" has to date encompassed twelve separate and distinct projects, seventeen if the aquaculture projects are categorized individually. In theory, any one of them could have been funded, sponsored, and managed directly from AID. In one sense, therefore, the Manager could be considered dispensable. This is not really a clear cut issue. Were the Program's goals purely technical, i.e. forecasting climate, establishing better erosion control, etc., there's really not much reason beyond inhouse technical competence why the AID staff could not administer each project separately. In turn, this would depend to a degree upon the wishes and philosophy of the Egyptians and Israelis.

Because the Program's fundamental goals are at least as much social as they are technical, however, the Steering Committee, composed of the Program's managers, who conduct the communications, coordination, advanced planning, and composite reporting, believes itself to play a necessary and beneficial role in the Program's development. As the Program progresses, however, and its personnel grow to know each other and to attain comfortable working relations, management's role may diminish somewhat. Of course, management's function in seeking out new topics, new players, and (hopefully) new countries to involve in the Program must continue. Put another way, the American "technicians" roles ought to diminish in time; our "ambassadorial" roles ought probably never to be relaxed.

The fifth issue relates to recruitment of other countries. Clearly, the "moderate" nations ought to be courted. Two recommendations are offered: Timing is important; attempting to rush these groups into cooperation with Israel will become a self-defeating movement. On the other hand, many professional "Middle East Watchers" aver that there has never existed, nor may there ever exist again, a healthier opportunity to decrease tension in the Middle East. The sixth issue concerns coordination, cooperation, and communications among the major Regional Cooperation Programs. There is none. This is ironic, considering the pioneering nature of the overall program. It would seem logical that management innovations would hardly be limited to any of these four programs and that the overall program would benefit from opportunities to compare notes, etc.

In 1983, at my suggestion, USAID convened a meeting of Program coordinators. Although it was clearly beneficial, it was not repeated. In 1986, AID awarded a contract to an external foundation to convene a large-scale workshop, which was held on Capitol Hill. Although it was carried out on a broad, lavish, scale, the ultimate benefits were never discernible. Much more recently (December, 1990) a high level review was conducted. It was insightful and comprehensive, and if implemented intelligently by USAID, will prove highly beneficial.

PROSPECTS FOR INTERNATIONALIZATION

At the instigation of the Egyptian coordinator, our Steering Committee has issued a document, hopefully of possible historical significance. Known as the "Aqaba Plan," it deals with the Gulf of Aqaba, a small, economically crucial, ecologically stressed, semi-enclosed body of water, common to Jordan, Saudi Arabia, Egypt, and Israel. The Plan purposes a collaborative program with the other Arab nations, without giving up, but keeping separately collaborative, its cooperative projects with Israel.

This rotated "parallel bilateral" approach would effectively bring about broad de facto cooperation among Israel and her Arab neighbors, and would seemingly advance U.S. interests significantly in the Middle East. It would provide the most dramatic benefit of a COSU operation ever witnessed. While apparently imaginative, farsighted and courageous, however, the plan may or may not be colinear with current U.S. policy.

For instance, strict interpretation of the law prohibits the use of Regional Cooperation funds for any uses external to Egypt and/or Israel. This curtails the practical travel of the "missionaries"to other countries.

Moreover, additional funding, which would be mandatory, appears chancy at this time. Some supporters, most prominently our outstanding Ambassador to Cairo, Frank Wisner, strongly advocate external — i.e. matching — funding for this purpose.

About two dozen private foundations have thus been approached. The universal response is that the Program, while "fantastic" in appearance, is too far removed from anything they have been accustomed to support. They are thus unwilling to stretch their charters, particularly in an era when they are under such stress.

Ultimately, however, such matching foundation support will have to be located, if the Program's viability is to be maintained. Yet as COSU I demonstrated, COSU-type programs are almost universally government funded.

THE FUTURE

Future aims include:

1. Adding new COSU technologies, institutions, and people to the Program, to spread its beneficial influence throughout as many communities as possible in the two countries;
2. Conveying the Program's benefits to other Middle Eastern and African countries in an effort to persuade them to join the Program;
3. Translating the scientific achievements into economic and cultural gains; and
4. Persuading U.S. Government officials that this Program's charter, motivation, and progress merit at least one fifth of the one percent of what this country spends on aid to the Middle East.

As we look to the future, the Program's leaders don't envision a smoothly rising curve of acceptance and participation. We would prognosticate, rather, a sort of step-wise motion as one after another, the social and financial barriers give way to good fellowship, beneficial technology, and — above all — common sense. The personal aspirations which we pretty much share in common include:

a) Acceptance of the Program in USAID and an attitude of if not unbridled enthusiasm — at least sensible encouragement;

b) Acknowledgment of the Program's achievement and recognition of its extraordinary potential at the top management levels of both the Executive and Legislative branches of the U.S. Government;

c) Continuing willingness of the Middle East partners to appreciate each other's eagerness to cooperate and to recognize each other's capability.

In summary, we the Program's practitioners, believe we are in process of demonstrating what history may term the ocean's greatest gift to mankind: Peace!

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The 301(h) Waiver and the Clean Water Act in Southern California

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ABSTRACT

Throughout the late 1970s and 1980s Los Angeles city and county government fought implementation of the Clean Water Act. An amendment to the Clean Water Act was used to delay full secondary treatment of sewage before the sanitation districts sent the effluent into our coastal waters. This amendment is known as the 301(h) waiver.

This waiver is to be used when delaying such treatment will not harm the local marine ecosystem. Historically, the dumping of toxic waste into the southern California coastal waters during the 1940-1970 period created a wasteland of sorts that now has some of the most toxic fish in the world. Yet these waters were also considered for waiver status in the 1980s and a waiver status was granted to the City of Los Angeles in 1981. Sewage sludge was also dumped into the local waters off Los Angeles county beaches. In 1985 a groundswell of public opposition to this continued abuse of the coastal waters of Southern California and the lack of understanding by the leaders in government created a classic confrontation. By January 1991 the EPA had denied the city and county waiver status regarding the secondary treatment issue and the dumping of sewage sludge was halted.

This situation provides an example of how citizens who participate in the system can change our world. It is also an example of how local, state and federal government can work in a bipartisan effort to pollute our environment.

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THE 301(H) WAIVER

Over the past decade we have seen why delaying the environmental laws of the land are self-destructive for the environment and government. Often the will to meet the demands of environmental law are hard and confusing, but in the long run the payoff is worth the costs in the short-term.

In Los Angeles County the 1980s began with a debate about the Clean Water Act. A conservative Republican President entered the White House with a new agenda regarding the environment, which did not emphasize enforcing the goals of the Clean Water Act which Congress had passed a decade before. Los Angeles was growing in population like no other region in the United States and development was king. Although a Democratic government controlled City Hall, the policy of avoiding the demands of the Clean Water Act seemed to match that of the Reagan Environmental Protection Agency (EPA).

The EPA granted Los Angeles a 301(h) waiver, which allowed the city to avoid moving to full secondary treatment of waste water and continue down the path of a developer's dream. But by 1985 things began to change, as EPA came out of a major congressional investigation and the Los Angeles County Sanitation district began to feel public pressure as the infrastructure began to tremble.

As hearings began to evaluate the waiver situation a development company moved to push through plans for a massive plan beside a local wetlands. But as city government election politics began to roll, the supporter of the plan was attacked and defeated for selling out to developers. Meanwhile, as the waiver hearings moved on the city government was providing experts who claimed that raw sewage provides "organic enrichment" to the local coastal waters. Following this testimony, scientists who worked for the sanitation districts came out into the public arena to state that their data was being manipulated to provide ammunition for those interests in local government that wanted to delay secondary treatment at all costs.

In the summer of 1985 raw sewage spills soiled beaches along the southern California coast during the peak summer season as millions flocked to the county beaches. The infrastructure was at a crisis, as several hundred thousand people moved into California each year and hotel construction boomed. The sewage system was at its limit of capacity. The slightest power failure or rain storm overwhelmed the old system, sending untreated sewage into the ocean, closing beaches for days.

Environmental groups actively entered into the situation soon after this event, asserting the concerns of the Clean Water Act. Heal the Bay was formed that year, 1985, and with the Coastal Waters Task Force of the Sierra Club, began a forceful and well organized mission to move towards full secondary treatment in those crisis days, as sewage closed beaches and Los Angeles city and county government continued to deny the need for better sewage treatment.

By simply agreeing with such organizations as the Department of Fish and Game, Heal the Bay stepped in as the major force in a large grassroots movement to halt the waiver application process. Housewives and professionals, from desk clerks to lifeguards, and a handful of longtime activists from west Los Angeles began to meet and share information about the deficiencies in the city and county waiver applications. They planned a clear set of actions which would help to undermine the granting of a waiver. By December 1990, both the city and county waivers had been reversed and a secondary treatment plan was developed for Santa Monica Bay.

Unfortunately this decade of delays has greatly increased the eventual cost of complying with the goals of the Clean Water Act. The money the federal government once made available to local government was eliminated by the Reagan administration in the early 1980s. Beyond the elimination of federal grants, the massive debt of the state government has hampered local and regional efforts, as population growth and development increases demands on the infrastructure.

Some federal funds have been made available through the National Estuary Program, and with the help of former Congressman Mel Levine, to help rehabilitate Santa Monica Bay. A new understanding of the importance of coastal resources to this region's economic and social future will help propel local and regional government toward healing our valuable coastal zone.

(Edited by P.M. Grifman)

Technical Papers on Waves and the Design of Coastal Structures

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Estimation of Design Wave Heights for Coastal Structures

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ABSTRACT

The planning and design of any coastal or offshore structure is largely governed by the behavior and magnitude of the ocean waves occurring at the site. The determination of long term design wave heights is normally made by following an empirical statistical procedure. This technique, however, involves some anomalies — e.g., it assumes that the conditions of wind speed and fetch responsible for wave generation are directionally unbiased. It also extrapolates sea states in direction sectors with restricted fetch beyond a physical upper limit.

An alternative procedure attempting to eliminate such discrepancies is discussed in this paper. It involves convolution of directional probability distributions that are statistically best fitted to obtain an equivalent all-direction distribution on which basis the long-term wave predictions could be made.

INTRODUCTION

The estimation of extreme wave height corresponding to a specified return provides a basic input to the analysis and design of various coastal and offshore installations. It is based upon the short-term wind or wave observations collected at the site for a period of the order of a few years. The significant wave height, Hs, and the average zero upcrossing period, Tz, are derived from each short-term observation. This information gives cumulative probability distribution, P(Hs), for different Hs values. The observed probability distribution of Hs is then fitted to

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various theoretical probability distributions like Lognormal, Gumbel, Weibull and the best fit distribution is selected based on results of goodness of fit tests. It is further extrapolated to obtain the design Hs value corresponding to specified return period, Tr.[7]

The above procedure currently followed in the ocean industry does not account explicitly for the directions of waves or those of wind generating them. It is implied by the procedure that all wave directions are equally likely to occur and that the conditions of wind speed, U, and fetch, F, generating the waves are directionally unbiased. There is also an implicit extrapolation in this method at the sea conditions along different directions beyond maximum wave heights governed by corresponding fetch values. For any coastal location therefore this method may not be appropriate.

Deo and Burrows[3,4] therefore suggested the use of an equivalent all-direction distribution in place of the conventional omni-directional one. This equivalent distribution is to obtained by deriving first the conditional P(Hs) distributions along different directions, curtailing them up to the maximum (Hs) value permitted by fetch restrictions and then convoluting them.

It is however noted that the use of the conditional distribution is associated with lower statistical reliability due to smaller sample size involved.[5] This paper discusses a modification to the procedure followed by Deo and Burrows[3,4] to offset this problem. It mainly consists of the use of the best fit directional distributions in the derivation of the equivalent all-directional distribution.

It is to be noted that the estimation of extreme waves from different points of compass has some specific applications, e.g. in structural optimization[2] and this study could be useful in such applications as well.

THE REVISED PROCEDURE TO OBTAIN DESIGN HS VALUES

The revised procedure for the estimation of long term significant wave heights could be as follows: (1) collect the data of short-term Hs, Tz values along with the corresponding wind directions for as long a period as possible, (2) categorize the data into different direction sectors, (3) derive cumulative probability distribution, P(Hs), for various Hs values for each direction sector, (4) fit various theoretical probability distributions viz. Lognormal, Gumbel and Weibull to the directional distributions, (5) apply goodness of fit tests and select the best fit conditional (or directional) probability distribution, P(Hs/Θ), for each direction sector, (6) introduce appropriate wave height ceilings along each directions, Θ, (i.e., assume P(Hs/Θ) values as unity for all Hs values beyond the limiting value, (7) convolute all best fit directional probability distribution to get the equivalent all-direction distribution of Hs using the following equation:

$$P(Hs) = \sum_{\text{all } \Theta} P(Hs/\Theta).W(\Theta) \tag{1}$$

where W(Θ) is ratio of total number of sea states along the direction, Θ, to the total number of sea states in all directions. Thus impart weightage to P(Hs) according to the underlying sample sizes, (8) fit above points of [Hs,P(Hs)] to different theoretical probability distributions. By considering the goodness of fit tests, choose the best fit equivalent all-direction distribution, (9) obtain the long-term wave height Hs corresponding to the specified return period probability with respect to this equivalent all-direction distribution.

The above mentioned procedure was followed to analyze six different data sets. The first set pertained to a coastal location in the Irish sea as shown in Figure 1. This site was such that it involved severe restrictions on wave growth along different directions and hence was ideally suited for application of the above mentioned procedure. Ship-reported data for five open locations around the Indian coastline were also available in Hagben, et al.,[6] and estimation of design Hs values using the suggested procedure is made for these sites as well.

ANALYSIS OF DATA

Analysis of the Irish Sea Data

The values of the average wind speed and corresponding wind directions observed by a ship at 3 hourly intervals were available for a period of 7 years (from 1964 to 1970) for a location in the Irish sea shown in Figure 1. The values of the significant wave height, Hs, and the average wave period, Tz, were derived using the SMB technique for each short-term interval at 3 hours.[3] The total data of 19246 sea states was then divided into 8 direction sectors as per Figure 2. It was found that the total number of sea states along different direction sectors varied considerably from 918 to 4815. The fetch distances were in the range of 9.03 to 62.9 Nm for different direction sectors. A rose diagram representing the variations in the total number of sea states along different directions is shown in Figure 3.

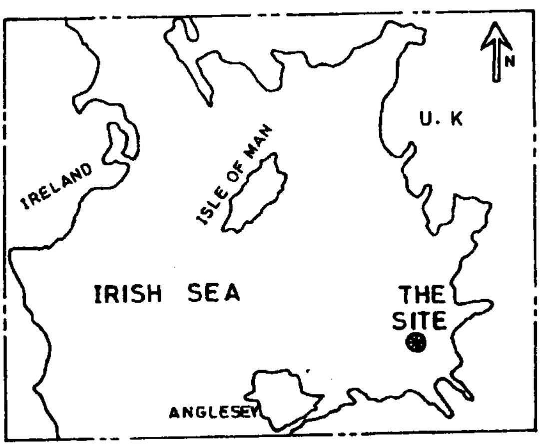

Figure 1. The site in the Irish Sea [1]

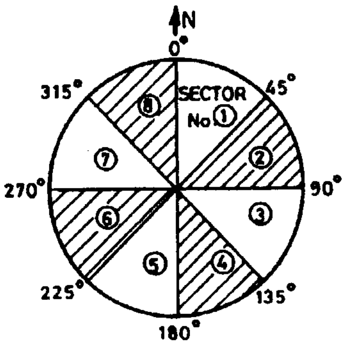

Figure 2. The direction sectors

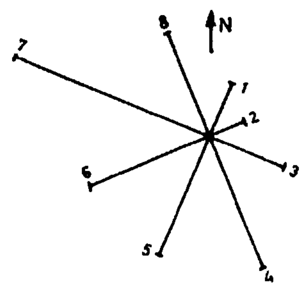

Figure 3. The Rose Diagram indicating total sea states along different directions

The limiting Hs value along each direction was obtained for an extreme hurricane wind force of 80 knots. From each directionally categorized scatter diagram of (Hs, Tz), the observed conditional long-term cumulative probability distribution of Hs was derived. It was fitted to theoretical moments. The Chisquare and Kolmogorov-Smirnov tests were applied to each fitted distribution to choose the best fit distribution. Appendix I gives all theoretical expressions involved. The computational aspects are discussed in Venugopal, 1991.[1] The Weibull distribution emerged as the best distribution for all sectors. Figure 4 indicates the various conditional distributions. These conditional distributions were further convoluted after applying the appropriate wave height ceilings as explained in previous section to get the equivalent all-direction distribution. Figure 5 shows the comparison of the omni-directional one obtained by the following the normal practice. As indicated in this Figure, the equivalent all-directional Hs value for 100-years return period was found to be 7.2 m, whereas omni-directional one was 7.95 m. This further indicates that the modified method results in the reduction of the 100-years Hs value by about 9 percent. While this is expected when the component directional probability distributions are curtailed as per the limiting Hs values, effects of different sampling sizes and fitting approximations may also be of some influence. This observation is in contrast to that of Deo and Burrows[3,4] who obtained an overestimation of Hs value by the equivalent all-directional distribution. However, use of single distribution (Gumbel) for all directions without ascertaining the relative goodness of the fit as well as categorization of the data into sixteen direction sectors (resulting in very low sample sizes) followed by them may not be appropriate.

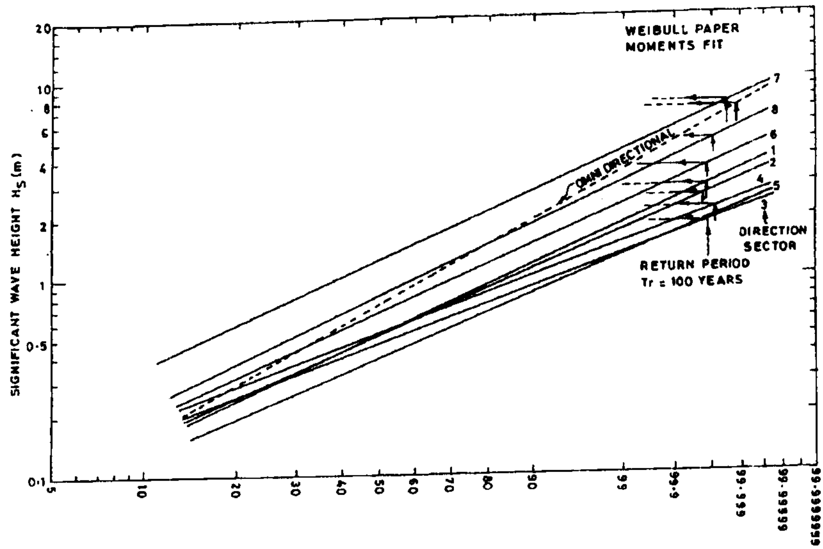

Figure 4. Best fit directional probability distributions (Site: Irish Sea)

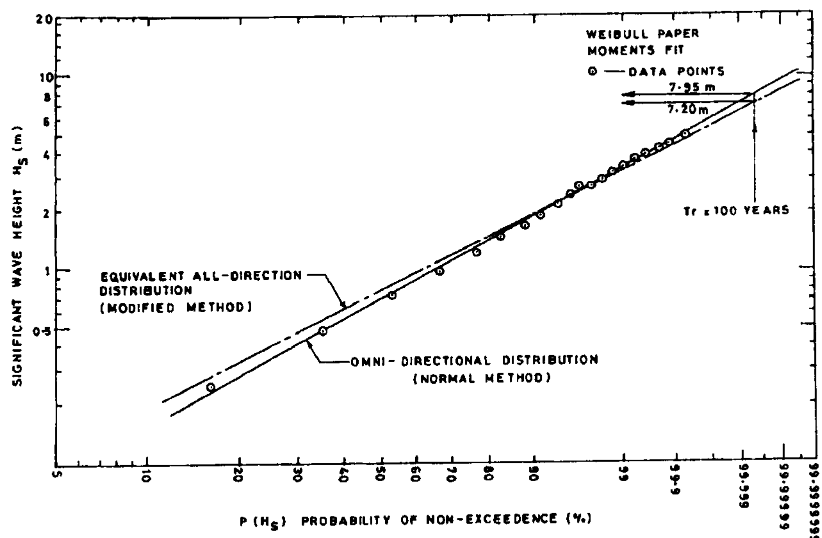

Figure 5. Comparison of distributions (Site: Irish Sea)

Analysis of the Indian Offshore Data

Hogben et al.[6] have presented the long-term scatter diagrams of Hs and Tz values for eight directions for 104 areas over the world. These values are based on the visual data reported by ships since 1854. A part of these data used in the present study is representative of the offshore environment around the Indian subcontinent and belongs to area 39, area 50, area 51, area 60 and area 61 (see Figure 6). The different direction sectors are shown in Figure 7. Figure 8 indicates the rose diagrams showing variations in percentage of sea states along different directions at these locations. It can be seen that in general the prominent direction sector corresponding to maximum number of sea states is S-Westerly. In case of area 51, annual data were not available and hence only seasonal data along SE and average of the annual data of N and W directions for NW direction are taken into account. The locations of data collection was assumed to be roughly at the center of each area and the fetch values for different direction sectors were worked out accordingly. Subsequently the limiting Hs values along each direction for each area were derived for an extreme hurricane wind force of 80 knots. These values varied from 9.75m to 18.6m.

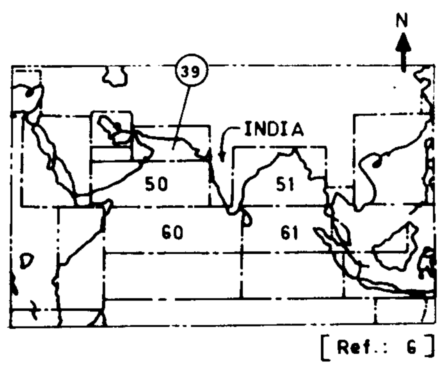

Figure 6. The Regions of Data Collection

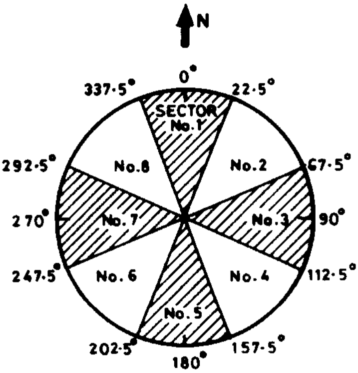

Figure 7. Direction sectors (Indian offshore)

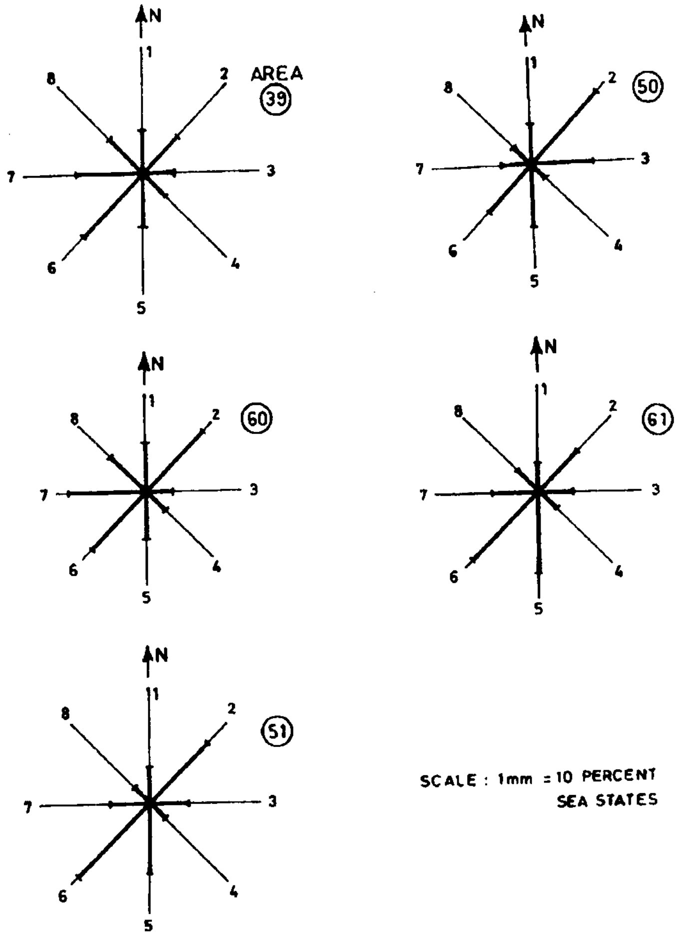

Figure 8. Rose Diagram showing percentage of sea states along different direction sector (Indian Offshore)

For each of the above five locations the equivalent all-direction distribution was derived by following the procedure similar to the one outlined in case of the Irish sea data described earlier and the values of the 100-year Hs were extracted from them. Venugopal, 1991 gives all details of the computational aspects involved.[1] Table 1 summarizes the salient features of the results obtained from the data analysis and also gives the comparison between the Hs values with 100-years return obtained both by following the revised as well as the conventional approaches.

Table 1

Summary of Analysis of Indian Offshore Data

Area	Best fit distribution against direction sectors	100-year Hs in m Omni-direction	Equivalent all-direction	Percent difference in Hs values w.r.t. omni direction
50	Weibull: 4, 8, omni-direction Gumbel: 1, 2, 3, 5, 6, 7	12.9	12.2	-5.4
51	Weibull: 1, 2, 3, 7, 8 Gumbel: 4, 5, 6 omni direction	8.2	8.0	-2.4
60	Gumbel: All sectors, Omni-direction	12.3	11.8	-4.1
61	Gumbel: All sectors	11.6	.6	-8.6
39	Weibull: All sectors	10.2	11.9	+16.7

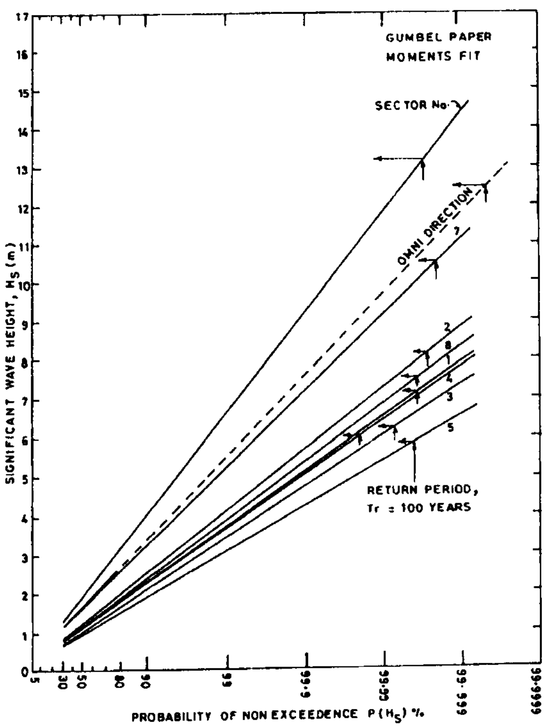

Figure 9. Directional probability distributions (area 60)

Figure 9 shows a typical plot of all best fit directional distributions for area 60 along with the omni-directional distribution obtained without categorizing the data as per the directions, while Figure 10 shows its comparison with the equivalent all-direction distribution for area number 60.

As can be seen from Table 1 the revised procedure of extreme wave estimation results in general in lowering the wave heights obtained by following the existing procedure. For areas No. 50, 51, 60, 61 the percentage difference in the "100-year" Hs values obtained by these two techniques varied from 2.4 to 8.6 The analysis of the data pertaining to area 39 indicates opposite behavior. However, for this set of data it was noted that none of the theoretical distributions was actually providing the best approximation to the observed values and the Weibull distribution was only relatively better when compared to Gumbel and Lognormal distribution. It is therefore felt that much significance need not be attached to the 100-year Hs values obtained for area 39.

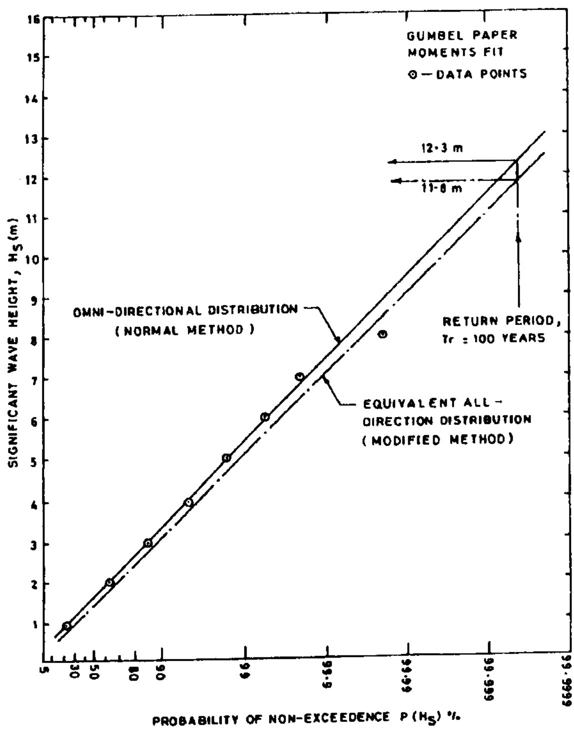

Figure 10. Comparison of distributions (area 60)

The reduction in the design wave height value estimated by the modified procedure for these areas cannot be attributed to the introduction of appropriate wave height ceilings along different direction sectors as in the case of the Irish sea location since areas are fairly open and limiting Hs values are very high. The influence of the fitting errors as well as that of the relatively lower sampling sizes underlying the directional distributions could be considerable in this regard. But consistent overpredictions by the existing procedure in five out of six data sets only indicates that ignoring the directional bias seems to result in increasing the probability of exceedence and reducing the probability of non-exceedence in the omni-directional distribution for a given wave height.

It is to be noted that the entire technique of long-term wave height estimation is purely empirical in nature and therefore a strong justification for adoption of any particular methodology cannot be given. However, from the point of view of removal of certain inherent anomalies in the conventional estimation procedure the method discussed in this paper may seem to be more reasonable statistically, especially for a coastal location with significant fetch restriction on wave growth even though it involves more levels of uncertainties and non-uniformities.

CONCLUSIONS

1. Some of the anomalies associated with the conventional technique of estimation of long-term wave heights at a given ocean site can be removed by following a modified procedure discussed in this paper. This procedure involves the use of the conditional wave height distributions along different directions to arrive at an overall distribution on whose basis the return period wave heights culled be extracted.

2. The uncertainties and possible fitting approximations arising out of low sampling sizes in each direction could be offset to some extent by categorizing the data into fewer directional sectors and by using the best fit directional probability distribution in deriving the all-directional probability distribution.

3. The use of the best fit distribution along various directions in place of any arbitrary distribution, considerably influences the resulting design wave heights.

4. The value of the significant wave height with 100 years return obtained by following the revised technique for a coastal site in the Irish sea was 9 percent lower than the one obtained conventionally without any directional consideration.

5. For the four offshore areas around Indian coastline the adoption of the revised technique resulted in general in producing the 100-year design wave heights that are lower by an amount varying from 2.4 to 8.6 percent than those obtained by following the normal technique. however, are 39 showed the opposite behavior possibly due to inadequate distribution fitting.

6. The procedure of long-term wave estimation is inherently empirical and hence any modification in it would have its own limitations. However, for better statistical reasoning, modified procedures discussed in this paper may be better suited for a coastal location involving significant directional bias.

ACKNOWLEDGMENT

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APPENDIX

1. Gumbel Distribution:

$$P(Hs) = \exp\left[-\exp\left(-\frac{Hs-A}{B}\right)\right] \tag{1}$$

where, P(Hs) = cumulative probability distribution function of Hs
Hs = significant wave height
A = location parameter
B = scale parameter

2. Weibull Distribution:

$$P(Hs) = 1 - \exp\left[-\left(\frac{Hs-A}{B}\right)^C\right] \tag{2}$$

where C = shape parameter

3. Lognormal Distribution:

$$P(Hs) = \frac{1}{\sqrt{2\pi}} \int_0^{Hs} \frac{1}{CHs} \exp\left[-½\left(\frac{\ln Hs - B^2}{C}\right)\right] dh \qquad (3)$$

Parameter Estimation by the Method of Moments:

1. Gumbel Distribution:

$$B = 6\,'Hs/\pi \qquad (4)$$

where Hs = standard deviation of observed Hs values

$$A = \overline{Hs} = (0.05752 * B) \qquad (5)$$

$\overline{Hs}$ = mean of observed Hs values

2. Weibull distribution:

Parameter C is found by solving:

$$\frac{\lambda}{K} = \frac{\Gamma(1 + 3/C) - 3\,\Gamma(1 + 1/C)\,.\,\Gamma(1 + 2/C) + 2\,\Gamma(1 + 1/C)}{[\Gamma(1 + 2/C) - \Gamma^2(1 + 1/C½} \qquad (6)$$

where $\Gamma(\ )$ = Gamma function of argument ( )

$$B = \frac{'Hs}{[\Gamma(1 + 2/C) - \Gamma^2(1 + 1/C)]^{½}} \qquad (7)$$

$$A = \overline{Hs} - K\ B\ \Gamma(1 + 1/C) \qquad (8)$$

where λ = skewness of the observed Hs values
K = 1

3. Lognormal Distribution:

$$B = 2 \ln \overline{Hs} - 0.5 \ln \overline{Hs^2} \qquad (9)$$

$$C = (\ln \overline{Hs^2} - 2 \ln \overline{Hs})^{½} \qquad (10)$$

Goodness of Fit Tests:

x^2 Test:

$$x^2 = \frac{\Sigma\,(Wexp - Wobs)^2 \text{ for all classes in scatter diagram}}{Wexp} \qquad (11)$$

Where x^2 = Chisquared statistics
Wexp = expected number of sea states
Wobs = observed number of sea states

Kolmogorov-Smirnov Test:

$$D_n = \frac{\max|Fei - Foi|}{N} \tag{12}$$

where D_n = distance statistic
Fei = expected number of sea states in the i th class
Foi = observed number of sea states in the i th class
N = total number of all sea states

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Research of Littoral Transport Rate and Wave Energy Analyses of the Bay Inside the Wai-San-Ding Barrier of the Taiwan Strait

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ABSTRACT

Wave energy and littoral transport rate are very important factors for the planning and design of harbor and coastal engineering. This research deals with analysis of the measured waves of the bay inside the Wai-San-Ding Barrier of the southwest Taiwan coast, supplementary and with the relationship between waves and winds for establishing the whole year wave energy. The littoral transport rate of the bay area inside the Barrier is simultaneously analyzed for providing design data for the maintenance of navigational channel and planning bases of the transportation shipping line between Putai, on this island, and Maakon of the Penhu offshore island.

The main contents of this research are:

(1) Analyses of the observed wave data of the offshore area of the Wai-San-Ding Barrier and the measured waves of the bay area inside the Wai-San-Ding Barrier. The wave decaying situation from offshore toward the bay area and the wave energy of the bay area are also computed.

(2) The relationship between the wind speeds and waves among the meteorological stations and wave stations is then established for the bases of the future prediction and analyses. Then, from the given meteorological conditions, the waves are computed by the relationship of the equation of the wave characteristics.

From the research in (2) the long term yearly wave energy is obtained and compared with the yearly littoral transport rate are the continuous yearly topographical change. The relationship between wave energy and the littoral transport rate is then obtained.

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INTRODUCTION

Due to the sheltering effect of the Wai-San-Ding Sand Barrier, hydraulic conditions in Putai harbor are quite favorable. Since this is a relatively well-protected area with regard to both waves and wind, no special navigational problems have to be planned for inside the Bay-Putai Port.

The wave energy of the Barrier is computed from the measured waves by considering the refraction effect down to the breaking line. Due to the lack of wave records, wind speed is used by applying regression equations among wave height, period and wind speeds, and then computing the wave height and period to obtain a breaking wave energy. Therefore, the total breaking wave energy (P) of the whole year along the Wai-San-Ding Barrier is summarized.

The littoral transport rate (I) is calculated using the mesh method by comparing the echo-sounding maps of two continuous years. Therefore, the relationship of P and I is correlated in the Wai-San-Ding Barrier for the Taiwan Strait.

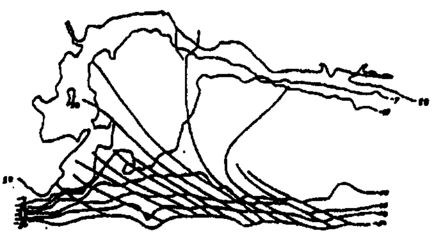

Figure 1-1. The wave refraction drawing of the Wai-San-Ding Barrier
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Calculation of the alongshore breaking wave energy

The wave data are recorded by the wave gauge at depth -15m per 2 hours in 1983 at Putai offshore area.

The wave is affected by the effects of shoaling, refraction, bottom friction and percolation. Neglecting the effects of bottom friction and percolation, as the wave is propagating toward the surf zone, the breaking wave height is equal to $H = HoKrKs$ where Kr and Ks are refraction coefficient and shoaling coefficient respectively. The mathematical representation is as follows:

$$Kr = (Bo / B)^{1/2} \tag{2.1}$$
$$Ks = (Cgo / Cg)^{1/2} \tag{2.2}$$

where B is the separation of the wave rays and prefix "o" represents the characters of deep water. As the bottom slope is smaller than 1/10 then Kr and Ks could be calculated from the four equations derived by Chao, Y.Y. (1970) as follows:

$$c^2 = \left(\frac{G}{K}\right) \tanh kh \quad (2.3)$$

$$\frac{d\Theta}{ds} = \frac{1}{c}\left(\sin\Theta \frac{\partial c}{\partial x} - \cos\Theta \frac{\partial c}{\partial y} = -\frac{1}{c}\frac{dc}{dB}\right) \quad (2.4)$$

$$H.(C_q).B. = H\,C_q\,B = \text{constant} \quad (2.5)$$

$$\frac{dB}{ds} - p^{(1)}\frac{dB}{ds} + p^{(2)}B = 0 \quad (2.6)$$

$$p^{(1)} = \frac{1}{c}\left(\cos\Theta \frac{\partial c}{\partial x} + \sin\Theta \frac{\partial c}{\partial y}\right) \quad (2.7)$$

$$p^{(2)} = 1/c\left(\sin^2\Theta \frac{\partial^2 c}{\partial x^2} - 2\sin\Theta\,\mathrm{soc}\Theta \frac{\partial^2 c}{\partial x \partial y} + \cos^2\Theta \frac{\partial^2 c}{\partial y^2}\right) \quad (2.8)$$

where D is water depth, ? is the angle between the X axis and wave direction, S is the distance along wave ray and C is the phase velocity.

As shown in Fig. 2.1, the X axis is taken parallel to the shoreline. Developing numerical calculations to get "The Wave Character Computing Program," (Hou et al., 1980) the wave characters such as Kr, Ks, H, Cg and could be found out at any water depth h=D (Figure 2).

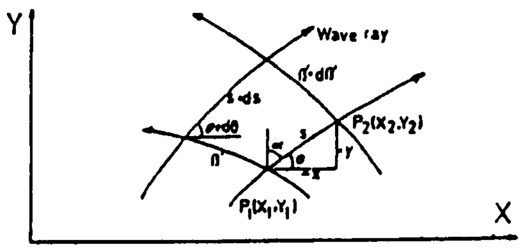

Figure 2.1. Diagram of the wave refraction

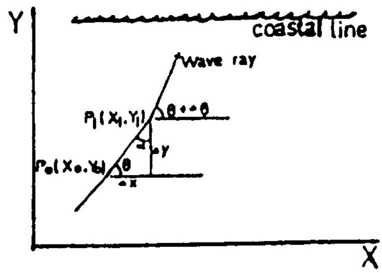

Figure 2.2. Diagram of the wave refraction

Since there are no records of wave direction at -15m depth, the incident wave direction is found by the above program using the deep water incident wave direction, which is the wind direction taken from the wave gauge.

Consider that only the waves which are moving onshore could cause littoral transport. The waves which have the same incident direction are summed up. The root mean square value of their heights and the mean value of their periods are calculated. Therefore, the total onshore acting waves are compiled to 8 equivalent waves which have the "rms" (wave height, Hrms, mean wave period T. This is because

$$\frac{(P\ell)_b}{M} \alpha H^2 \cos\theta \sin\theta \alpha H^2 \sin 2\theta \qquad (2.11)$$

$$\sum_{i=i}^{M} (P\ell)\, bi \; \alpha \left(\sum_{i=i}^{M} Hi^2\right) \sin 2\theta = M Hrms^2 \sin 2\theta$$

where M is the number of the waves which have the same wave direction, and Hrms is represented as

$$Hrms^2 = \frac{1}{M} \sum_{i=i}^{M} Hi^2 \qquad (2.12)$$

To compute the alongshore breaking wave energy, the input data including the water depths of the grid points, the water depths and the coordinates of the incident points, the Hrms values and the T values of the equivalent waves with the incident wave direction at the depth -15m of the offshore area, around Wai-San-Ding Barrier are all considered.

Relationship between Total Wave Energy and Littoral Transport Rate

Based on the analyzed result, the alongshore wave energy is 287,000 ton-m/m-yr, the corresponding littoral transport rate is 1.3 x 10^3 m^3/m-yr.

From the equation $Il = K(Pl)$, the value of K is then 3.5 x 10^{-3}. Therefore, the equation $Il = 3.5 \times 10^{-3}(Pl)$ is applied to the Wai-San-Ding Barrier. From the profile change of 1963. 1967 and 1980, they show that scouring occurring along the Wai-San-Ding sand barrier due to the supply of river sediment is lessened.

CONCLUSIONS AND SUGGESTIONS

Applying the energy approach for unidirectional steady flow (Bagnold, 1963), derived from the relationship between the alongshore breaking wave energy and the littoral immersed weight transport rate as $Il = K(Pl)b$.K. K is a function of wave height, bottom slope, the grain size and the sediment transport pattern. It increases as the grain size decreases or if there exists an ocean current in the predominant littoral transport direction or due to the action of the bigger waves. This reveals that the larger part of wave energy is supplied to transport sediment as wave energy becomes larger. This is shown by the empirical relationship $Il = 0.154\ (Pl)b$. But for a coast, such as the Taichung coast, where oceanographic conditions are so steady that the alongshore breaking wave energy fluctuates slightly, the relationship between Il and (Pl) could be written as $Il = K(Pl)b$, where K is constant. Then the Wai-San-Ding barrier the relation of $Il = K(Pl)b$. This equation could be applied for a coast with similar oceanographic conditions and beach characteristics to estimate the littoral transport rate. Harbor planning and the shore protection could be based on these calculations.

Littoral transport study upstream and downstream of the Wai-San-Ding sand barrier (Hou, 1985) and the wave decaying and refracting of the Putai new port (Hou et al., 1984), has been discussed. However, this paper deals with the measured data of wind speed, wind direction and wave, then detailed analyses obtain the whole yearly alongshore wave energy. The littoral transport rate is obtained from hydrographic surveys. Therefore, the formula of is very appropriate for computing the littoral transport rate. The field measured data is very precise, since the coastal area is widely, delicately surveyed, and accurate instruments are also used for this area.

The model of wave height and wave period is deduced from wind speed. It is a convenient and effective prediction model for wind waves. Therefore, it could be applied and referred to ocean and coastal engineering use. However, the applicability of different wind conditions in different seasons need to be carefully considered.

As the shelf wind waves entering the offshore area due to the effect of Wai-San-Ding sand barrier, and then wave diffraction is shown, waves will change their direction, especially during the winter season. Therefore, waves coming from NNE and N directions will turn NNW and then dissipate over the beach.

The calculation of wave energy along the Taichung harbor coast (Hou, et al., 1980) is higher than that of the Putai harbor site. Since the waves of the latter are sheltered due to the Wai-San-Ding Sand Barrier, the offshore wave energy decays and decreases largely as it reaches the Putai harbor site.

ACKNOWLEDGEMENT

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Theoretical Analysis and Experimental Research of Wave Force on Deep Water Breakwaters

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ABSTRACT

Deep water port development and construction play an important role in harbor planning in Taiwan District. Theoretical and experimental analysis of wave forces on deep water breakwaters has rarely been undertaken, however. Probably because of improper use of design theory or the lack of examination of some major properties of wave force, failure of some deep water breakwaters has occurred.

For such cases, it is necessary to analyze the properties of wave forces in deep water breakwaters and to utilize design theory to understand the forces on breakwaters in finite water depths. This research project deals primarily with wave forces produced by regular waves on deep water breakwaters. Utilizing mathematical models to analyze the properties of high order standing wave pressure and non-linear deep water wave pressure duration curves enables comparisons of the important properties of front wall and back wall wave pressures on the deep water breakwater.

Experimental aspects are matched with theoretical analysis, by calculating the relationships of depth and incident wave steepness, and then measuring the wave pressure characteristics of deep water breakwaters. Experiments involve wave pressure duration curves and wave pressure distribution on the vertical breakwater section, including characteristics of the microseisms occurring from the bottom of deep water breakwaters due to standing wave action. In addition, the impact of breaking wave pressure is investigated. The irregular wave pressure characteristics of deep water breakwaters will be studied in the next phase. These research results will yield suggestions for the design of future breakwaters.

International Perspectives on Coastal Ocean Space Utilization
Phyllis M. Grifman and James A. Fawcett, Editors

INTRODUCTION

For dealing with the construction problems of the deep water breakwater, as for example, the caisson composite type breakwater, foundation work is the problem as the breakwater goes into deeper water. Due to the limits of divers in deep water, placement of the mattress, leveling of the mound, etc. are problems. For deep water construction, planning and design of the structure is critical.

In planning a breakwater, the necessity of a huge deep water structure needs to be considered with regard to:

1) Investment benefit: Due to the expense of engineering the deep water breakwater, if, after construction the benefit is not expected to be larger than the investment cost, the breakwater should not be built.

2) Alternative plans: For elongation of an existing breakwater to a deeper position, the construction of a new breakwater in shallow water may have the same function for the harbor. Enlarging and repairing an existing wharf could be a more efficient solution for a particular harbor.

3) Calm wave sheltering area: Due to the high cost of a deep water structure, it may be possible to cut down the elongation of the breakwater; however, the harbor basin needs to be calm.

FORMULATIONS

The coordinate system used in this paper is that reported by Hsu et al. (1979). Set $k=2\pi$ / L, L is the wavelength of the incident wave, and the following dimensionless quantities are introduced: $\hat{x}=pkx-\sigma t$, $\hat{y}=qky$, $\hat{z}=kz$, $\hat{d}=kd$, $\hat{\eta}=k\eta$, $\hat{\phi}=k^2\phi/(gk)^{1/2}$ and $\omega=\sigma/(gk)^{1/2}$.

Omit the carets, then the governing equations are transformed in terms of dimensionless form as followings:

$$p^2\phi_{xx}+q^2\phi_{yy}+\phi_{zz}=0 \qquad (1)$$

$$-\omega\phi_x+\eta+(p^2\phi_x^2+q^2\phi_y^2+\phi_z^2)/2=Q \quad \text{at } z=\eta \qquad (2)$$

$$\omega^2\phi_{xx}+\phi_z-2\omega(p^2\phi_x\phi_{xx}+q^2\phi_y\phi_{xy}+\phi_z\phi_{xz})$$
$$+2(p^2q^2\phi_x\phi_y\phi_{xy}+p^2\phi_x\phi_z\phi_{xz}+q^2\phi_y\phi_z\phi_{yz})$$
$$+(p^4\phi_{xx}\phi_x^2+q^4\phi_{yy}\phi_y^2+\phi_{zz}\phi_z^2)=0 \quad \text{at } z=\eta \qquad (3)$$

$$\phi_z=0 \quad \text{at } z=-d \qquad (4)$$

$$\phi_y=0 \quad \text{at } y=0 \qquad (5)$$

in which $p=\sin\theta$, $q=\cos\theta$ and θ is the angle between the incident orthogonal and the normal to the wall, Q is the dimensionless constant.

A truncated double Fourier series which satisfied both Laplace equation (1) and the bottom and the wall boundary equations (4)(5) can be obtained that

$$\varnothing = \sum_{m=1}^{M-1} \sum_{n=0}^{2N} B_{mn} \frac{\cosh \alpha_{mn}(z+d)}{\cosh \alpha_{mn} d} \sin mx \cos ny \quad (6)$$

where $\alpha^2_{mn} = p^2m^2+q^2n^2$. As (m+n) is odd, B_{mn} is equal to zero from the symmetry of the wave problem. Substituting (6) into the free surface boundary equations (2) & (3), two nonlinear equations with the implicit function of surface elevation (x,y,t) are performed.

For the purposes of numerical computation, the mesh points (x,y) are chosen by the even symmetric properties given by

$$x_i = i\pi / M, \text{ for } i=0,1,2,...,M \qquad (7)$$
$$y_j = j\pi / 2N, \text{ for } j=0,1,2,...,N$$

Substituting (6) into (2) at the mesh points (x_i,y_j), it obtains (M+1)(N+1) algebraic equations. While (6) is substituted into (3), the equation is automatically satisfied at the points

$$(x_{mv}y_n),\ (x_o y_j) \text{ and } (x_m,y_j),$$

and the values at the points $(x_{m-1}y_n)$ are equal to that of (x_1y_n) (for i= 1,2,...,M / 2-1) from 3) at the trigonometric symmetry. Then satisfied (3) at the remaining points leads to (M-1) N+M / 2-1 equations. Besides, the wave height condition can be established by:

$$n_{\infty} - n_{m0} - H = 0 \qquad (8)$$

where n_{ij} represents $n(x_v y_j)$. This is the waveheight of the shortcrested wave. The mean water level of free surface is chosen at the coordinate origin, using the simple trapezoidal rule then

$$\frac{\pi^2}{8MN} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} (n_{ij} + n_{i-1j} + n_{ij+1} + n_{i+1j+1}) = 0 \qquad (9)$$

Consequently, there are 2MN+3M/2+2 nonlinear algebraic equations for the 2MN+3M/2+2 unknowns $B_m n_{ji}$, ω, Q.

This system is solved by Newton's iterations. It is noted that M is chosen in an even number.

TEST RESULTS AND ANALYSES OF DEEP BREAKWATER OF CAISSON-COMPOSITE TYPE

Around the Taiwan coast, especially the international trade port, a breakwater of the caisson composite type is commonly used. Deep outer breakwaters of the 2nd entrance of Keelung Harbor are tested for impact pressure analyses. The typical design section of 35m deep is shown in Figure 1; while the wave pressure pattern is shown in Figure 2. The strong impact pressure (Figure 2c) is about triple the normal wave pressure, its period is about 1/7 to 1/20 sec. In addition to the breakwater of the 2nd entrance of Keelung Harbor, the varying mound shape and the mound height of caisson composite breakwaters are tested and analyzed for further new information.

Figures 3 and 1 show many cases of test results, the results showing that with the higher mound of the caisson composite breakwater (d/h=3), wave pressure increases as the wave height becomes large; therefore the mound height has an obvious effect on the wave pressure. The varying transverse width of the mound also shows that wave pressure is larger as the transverse width of the mound is wider, the wave pressure bigger as the mound height is higher.

Figure 5 shows that the impact wave pressure occurring in the range of the deep water breakwater has the same tendency as that in shallower depth. That is, as d/h is smaller (or higher mound), the occurrence of the impact pressure is high. The case of no wave overtopping is easier than that of wave overtopping. The impact pressure occurring range is indicated by the dot line of Figure 5.

RESULTS AND DISCUSSION

The caisson-composite breakwater is designed so that armour concrete blocks such as dolos, hollowtripod, etc. prevent wave action directly toward the caisson from forming shock pressure (one form of impact pressure). By using the porosity of armour concrete block to increase turbulence for dissipating wave energy; wave pressure should be minimized. Based on the previous test results, it is considered that in front of composite type, the covering layer of armour unit on the mound could reduce the wave pressure about 60% in the shallower water area. However, reducing wave pressure depends on water depth, wave condition, mound height, mound slope and mound shape, etc. The present test results (test section of -35m deep or more) show that the portion of caisson (vertical wall) subjected to standing wave or part of a breaking pattern, the cover layer of armour unit is such that the wave acting on the slope forms the breaking wave and produces shock pressure (strong impact pressure) in a short time. The impact pressure is quite huge, therefore, the placement of armour concrete unit is inefficient to the wave action and will have a negative effect; therefore, it is suggested that the design section change to the section as shown in Figure 6.

NUMERICAL RESULTS

The forces exerted on the wall by the shortcrested waves can be calculated by integrating the pressure over depth per unit width of the wall.

Here, the Bernoulli equation is used for the pressure P(x,y, z,t). While the dynamic forces [F] due to the waves are introduced, the hydrostatic contribution of the undisturbed water must be deducted.

$$F = \int_{-d}^{\eta} P(x,0,z,t)dz \qquad (10)$$

In the following results, the calculated term M=2N=8 is taken. Because the wave elevation is preserved in an implicit function form, the accuracy can be under controlled even though the waves are steep. Figures 7 and 8 show that the accuracy arises from comparisons of the residual surface pressures of the steep waves in the shallow water depth. The following results can also be drawn: (i) The greatest onshore forces do not always occur under wave crests (see Figure 9), analogous to Fenton (1985). (ii) The maximum force in water greater than intermediate depth is caused by obliquely-incident waves rather than standing waves (see Figures 10, 11, 12). This behavior is opposite in very shallow water (see Figure 13). (iii) When water depth is greater than intermediate, the greatest net force exerted on vertical walls occurs in the offshore direction under the wave troughs (see Figures 10, 11). (iv) Compared against experimental data results from this research show better agreement than former studies (see Figure 14).

FAILURE OF DEEPWATER BREAKWATERS

Failures to deep water breakwaters have occurred over the past decade due to the following (main) reasons: Rubble Mound Type: the increase of depth and related increase of design wave heights led to designs with very steep slopes and protected by concrete armour units of weights and sizes far in excess of previous experience. The strength of these concrete blocks appeared in many cases to be insufficient due to the high peak forces, which occur on the blocks during a storm. The blocks broke and were subsequently easily removed from the slope. The great steepness of the slopes may also have contributed to failure, since the geotechnical stability of the mound becomes critical under wave loading. Vertical Wall Type: failures to this type of breakwater occurred mainly due to high impact forces of breaking waves at the vertical front, leading to horizontal displacements of the caissons and in some cases to geotechnical instability of the foundation and tilting.

The author has been invited in many cases of breakwater failure to investigate the failure and make a design for repair, e.g. Su-Ao Harbor Breakwater and Hualian Harbor Breakwaters on the east coast of Taiwan, R.O.C. The solution to the problems mentioned above lies primarily in following the proper design procedures, as applied by Hou (1978, 1980) throughout its breakwater projects. The main features of this procedure are systematic failure analysis of each design and an integral approach, including hydraulic, geotechnical and concrete strength aspects in a balanced way.

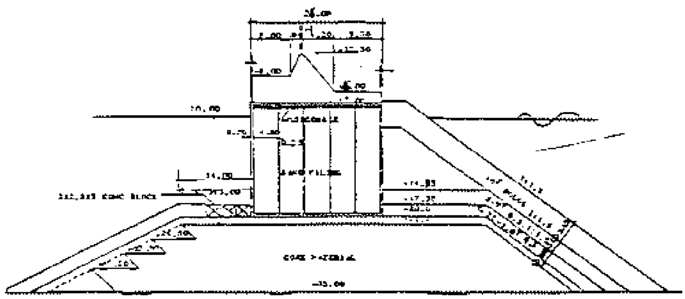
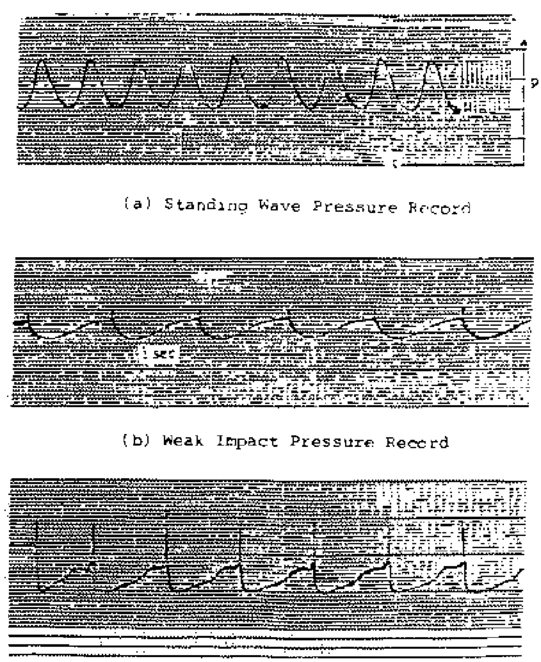


Figure 1. Deep Caisson Composite Type of Bah-Tsu Meng Breakwater at the 2nd Entrance of Keelung Harbor



(a) Standing Wave Pressure Record

(b) Weak Impact Pressure Record

(c) Strong Impact Pressure Record

Figure 2. Wave Pressure Pattern

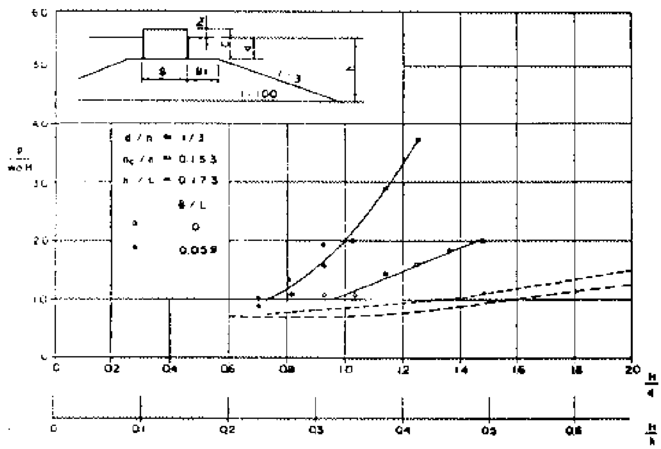


Figure 3. Mound Shape Affects the Wave Force Diagram

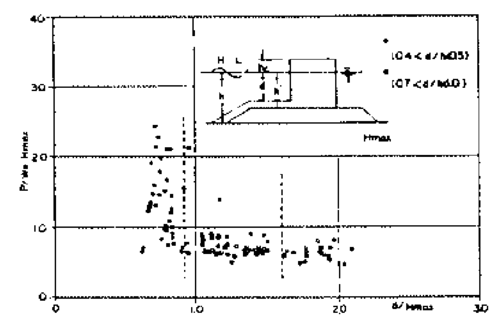


Figure 4. Mound Depth Affects the Wave Force Analyses

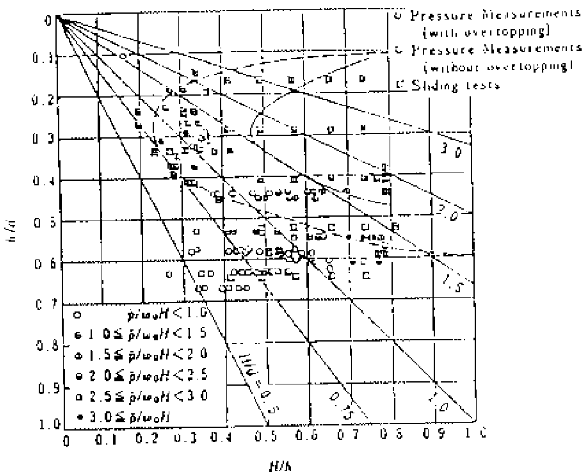


Figure 5. Possible range of the occurrence of impulsive breaking wave pressure

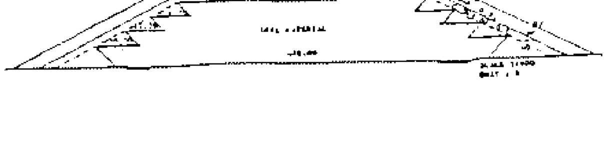


Figure 6. Modified Design Section of Deep Breakwater of 2nd Entrance of Keelung Harbor

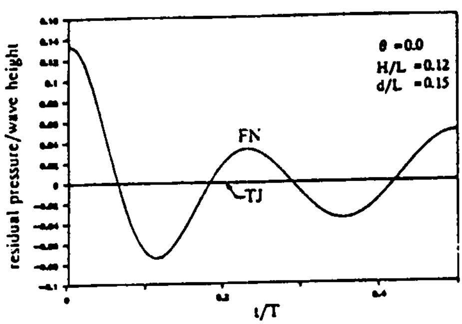


Figure 7. Variation of residual surface pressures with phase of time
TJ = Tsai & Jeng (present) FN = Fenton (1985)

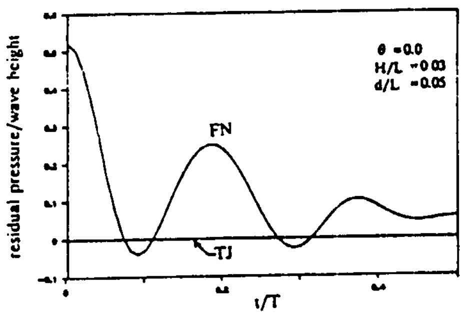


Figure 8. Variation of residual surface pressures with phase of time

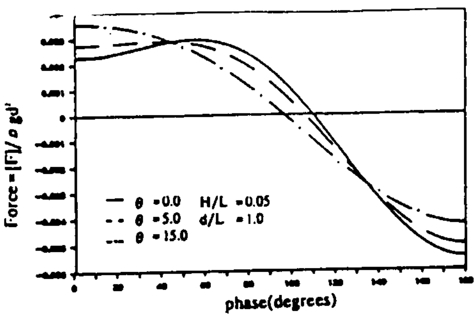


Figure 9. The greatest forces per unit length of each phase

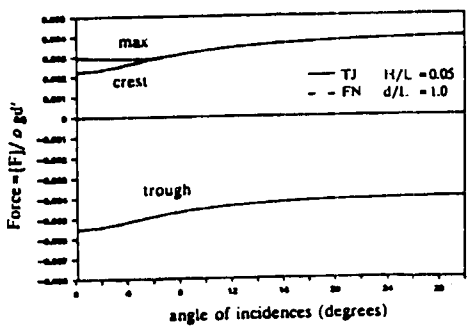


Figure 10. Variation of forces per unit length with angle of incedences

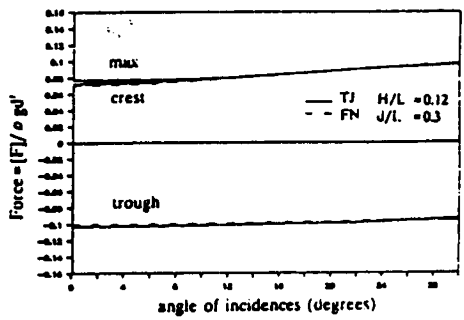


Figure 11. Variation of forces per unit length with angle of incidences

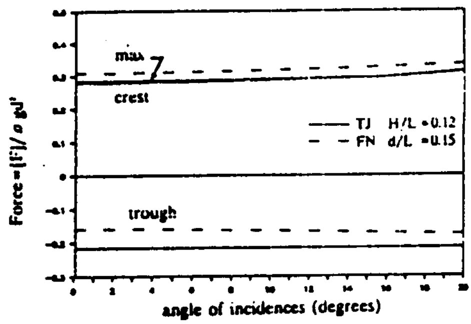


Figure 12. Variation of forces per unit length with angle of incidences

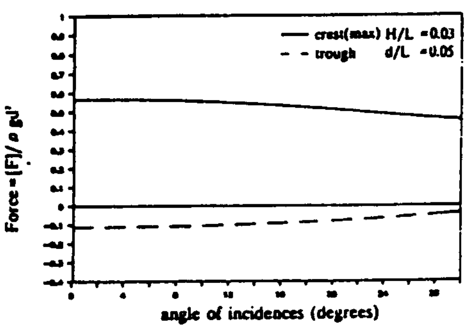


Figure 13. Variation of forces per unit length with angle of incidences

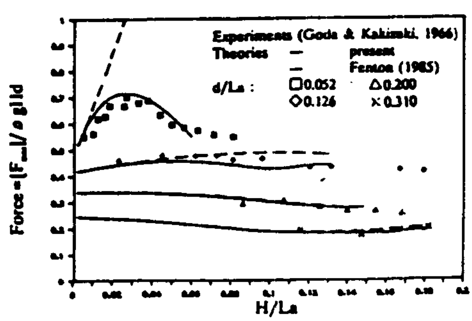


Figure 14. Comparison of the maximum of forces (La: wavelength of linear approximation)

CONCLUSION

1. For deep water breakwater construction, the field measurement of deep water wave, geological oceanographic data, foundation and earthquake problem, etc. need to be further studied.

2. For the caisson-composite deep breakwater, the higher mound is incurring the impact pressure, the lower mound has little such phenomena.

3. The wider the transverse width of the caisson composite breakwater, pressure is higher, more impact pressure may occur. However, for the vertical caisson breakwater (no mound outside the harbor) only, impact pressure may not occur.

4. For deep water breakwater design, if the width of the caisson is limited by bearing capacity, increasing the width must be considered.

5. As for the enlargement of caisson breakwater in deep water, its problems of design and construction need to be solved. Some hydraulic experimentation needs to be conducted after design and before construction of the deep caisson composite breakwater.

6. For the deep water port at the western coast of Taiwan, breakwaters will be found in maximum water depths varying from 15-50 m, depending on the layout of the type of breakwater in less deep water (15 m). A rubble mound type is preferable, while in very deep water a composite type breakwater will be more feasible. For wharves, vertical walls are envisaged, provided that the tranquility level inside the port can be achieved.

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(Edited by P.M. Grifman)

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