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MIT Sea Grant
Winter 1981

Quarterly Report

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Geotechnical Risk Analysis for Offshore Structures

Offshore construction is growing tremendously in the scramble for new oil and gas supplies. In some ways this building surge is outdistancing the experience engineers need to build in difficult environments. So, engineers commonly overdesign to avoid serious failures. Mostly this strategy has been successful, but the recent tragic collapses of platforms in the North Sea and China have dramatized how much more the offshore industry needs to learn.

According to MIT Professor Gregory Baecher, risk analysis offers one method of identifying and dealing with uncertainties that affect the performance of an offshore structure. "Though not perfect," he says, "risk analysis provides a reference for organizing results and combining them to draw consistent conclusions." It is a system of thought that helps break down a complicated problem into simpler parts, allows them to be analyzed in isolation, and then recombined to reach consistent conclusions.

When Baecher and a group of research assistants set out on their Sea Grant project in 1978, they ambitiously planned to quantify the aggregate geotechnical risk inherent in present offshore design. They soon discovered, however, that present statistical procedures and reliability models were inadequate to reasonably deal with the uncertainty faced by geotechnical engineers offshore. Instead they turned toward creating an approach to geotechnical reliability analysis that would correct deficiencies in present methodology while at the same time remaining practical. Ideally, according to Professor Baecher, risk analysis at any level of sophistication must be usable and answer clearly stated relevant questions. Finally, other people must be able to duplicate the results.

The risk analysis methodology is based on a common event-tree model. Graphically, the branches of the event tree serve as an organizing framework within which individual uncertainties and their interrelationships can be studied. It is mostly an accounting device for keeping track of chains of events that may lead to adverse performance. The individual and joint event probabilities are evaluated using statistical procedures, reliability models, and occasionally fault trees. Fault trees are constructed in the reverse order from event trees: they begin with an event (e.g., loss of strength stability in foundation soils) and progressively build smaller branches representing faults within the structures or foundation that must occur to lead to that event.

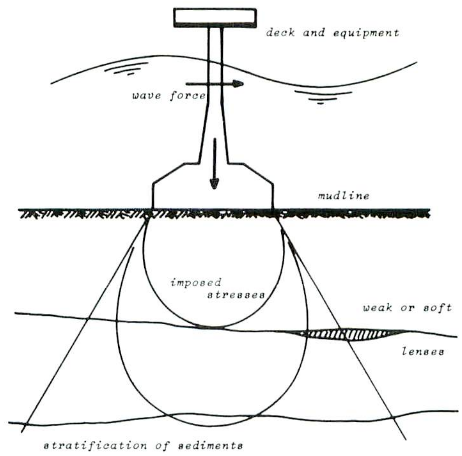


Figure 1. Typical profile view of offshore gravity platform.

To develop their analytical system, Professor Baecher's group concentrated on those sources of geotechnical uncertainty that alone, or collectively, affect the foundation performance of a gravity platform (a design which is stabilized by its own weight resting on the ocean bottom). They chose a hypothetical site on Georges Bank, an area scheduled for development in 1981, to test their analyses.

Baecher describes some problems facing offshore designers. "Geotechnical engineers in the course of their work are forced to deal with uncertainties seldom tolerated in most branches of civil engineering." Soil and rock masses are naturally variable, with little information to characterize them. Laboratory measurements can only approximate in situ conditions, and mathematical models are sometimes severe simplifications of the real world. Still, he believes that the risk analysis process forces objective, consistent treatment of information, observations, predictions, and design decisions. However, he also warns it must necessarily be subjective because the practitioner defines the parameters, is forced to make assumptions, and can omit a critical consideration.

In a state-of-the-art review, the Sea Grant-sponsored group attempted to extend existing methods for quantitative analysis of geotechnical uncertainty and combine them into a unified approach. The uncertainties introduced by modeling and the relationship of that uncertainty to parameter estimation developed into an important part of the study. While fairly well verified models are available for certain aspects of platform performance (e.g., static strength stability and deformation) other models and corresponding data are less adequate. For instance, liquefaction in noncohesive sediments under cyclic wave loading is only poorly understood. The researchers also concluded that previous analysis had neglected spatial variation in bottom conditions, seldom considered model uncertainties directly, and ignored interractions among failure modes.

The MIT researchers concluded that procedures for quantifying geotechnical uncertainties are rapidly advancing, although still dependent on the subjective nature of many uncertainties and on an inadequate understanding of soil behavior. Baecher says, "The potential contribution of quantified procedures for assessing uncertainties and incorporating them into analyses seems great, as long as their role within the overall issue of design and safety is not exaggerated." He cautions, "Like other methods of engineering science, risk analysis can aid but not replace human judgment." For the near future, the research group suggested that existing methodology should be applied to detailed case studies, in the hope of verifying procedures or identifying shortcomings.

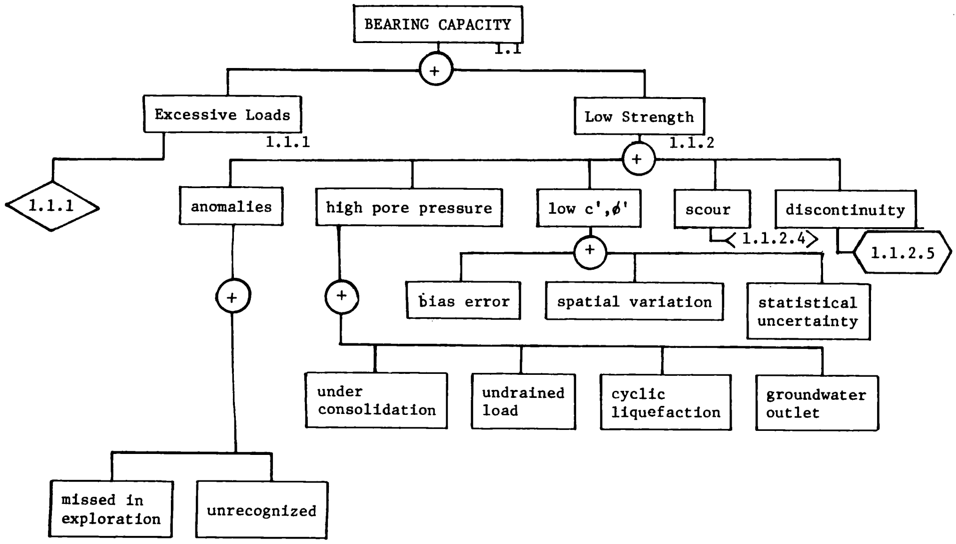


Figure 2. Sub-fault-tree for bearing capacity.

Engineering Special Foods from Chitosan

Steak, caviar and foods tailored to people with specific nutritional requirements or metabolic diseases may soon be engineered from chitosan, an organic compound derived from the shells of shrimp, crabs and lobsters. Using chitosan, MIT engineers at the Biomaterials Science and Fabrication Laboratory have synthesized basic structures whose textures and added ingredients could be controlled to simulate meats, fish, fruits and vegetables.

Many foods contain undesirable or harmful components for some individuals. The chitosan structures will permit the development of meat made without cholesterol for persons with heart conditions, and gluten-free bread for people allergic to wheat proteins. Professor ChoKyun Rha, principal investigator in the Sea Grant study, says that special foods containing no calories could be fabricated for dieters, and delicacies such as caviar and truffles could be synthesized at a lower cost. More significantly, the ability to control ingredients and texture allows freedom to create totally new foods.

Professor Rha, research scientist Dolores Rodriguez Sanchez and graduate student Carlos Kienzle Sterzer of the Department of Nutrition and Food Science have synthesized three basic chitosan structures—globules, structure matrices and films. Globules are small (approximately 3.5 to 4 millimeters in diameter), milky-white beads of pure chitosan. A structure matrix consists of a translucent network of chitosan sacs enclosing water; sacs can range in size from caviar to the sacs in orange pulp. Chitosan films are clear elastic strips resembling cellophane.

The researchers can control the dimensions and, to some extent, the texture of the chitosan structures. Texture is an important factor in the appeal of a food; no one wants to eat a soft potato chip or a tough steak. By characterizing the basic properties of chitosan and knowing what structures it will form under different conditions, Professor Rha believes that texture can be emphasized. The research group is testing such characteristics as swelling, mechanical properties, rupture, rigidity and elasticity of the newly developed structures, and comparing them with selected natural foods. In the future they will investigate methods of controlling texture to produce appealing duplicates of many foods, including surrogate steak and chitin caviar.

Industry can apply the MIT research results to further develop engineered foods. Professor Rha says, "We are interested in studying the basic structure synthesis. We expect industry to utilize the knowledge in product development and evaluation of commercial feasibility."

Sea Grant's interest in this project stems from a desire to help the fish processing industry find profitable uses for the chitosan in the thousands of tons of shell wastes that must be disposed of every year. Although chitin is the world's second most abundant biopolymer, trailing only cellulose, its utilization has been almost completely neglected.

Effect of Friction on Waves Interacting with the Seafloor

A strong wave heading over a flat sand bed starts the sediment moving, with a small initial dissipation of energy. After a short time, increasingly rough ripples form on the bottom, and energy dissipation grows. Interacting with the sediment, the flow of water generates a certain bottom roughness which determines how much energy is lost. "That link between water motion and bottom roughness—and the resulting rate of energy dissipation expressed through the concept of a friction factor—is the loop we're trying to close," says Professor Ole Madsen of the MIT Department of Civil Engineering.

In his Sea Grant project, Madsen is determining the effect of bottom friction on waves as they interact with the shelf floor. As Madsen describes it, "Storm waves generated in deep water start feeling the bottom, dissipate energy and have to travel long distances over the shelf bottom in decreasing water depth, feeling the bottom more and more and dissipating more and more energy." Because of this interaction, Madsen wants to account for the dissipation mechanism when predicting storm wave height and period at a certain location.

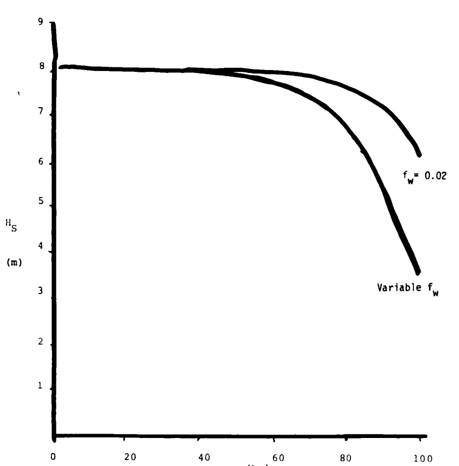
Madsen firmly states, "There's *no* reason to believe that just one constant friction factor would apply everywhere." For example, smooth clay regions account for a much lower rate of dissipation than very rough rippled bottoms. Medium high waves which generated steep ripples could be used to calibrate a model which would result in a very large friction factor. But if a severe storm wipes away the ripples, the lack of friction presented by the newly smooth bottom may reduce the energy dissipation significantly. In that case, the actual waves could be alarmingly larger than predicted by the model for medium high waves. As Madsen points out, "There's a very dangerous interplay. You'd think it was a proven model, but the conditions changed."

The first part of the research aims at establishing the relationship between wave characteristics, sediment characteristics, bottom roughness and friction factor. Investigators could then propagate a wave over an area of well defined sediment characteristics and predict the bottom roughness, friction factor, and amount of wave attenuation from knowing the bottom force caused by the wave motion.

As a first step toward a better model, Madsen analyzed previous results using parameters that are an empirical correlation between wave sediment and bottom roughness. Very steep ripples form when wave motion exceeds the severity at which sediment starts to move. If the waves get much higher, the steep ripples start to flatten out and can eventually disappear, as in the surf zone.

The variation in velocity at the bottom as a function of time can be represented as the summation of many different sinosoidal waves. "It's a spectral description of the bottom velocities which must be related to the friction factor and the dissipation, so that dissipation becomes a function of the frequency of the different wave components," says Madsen.

"We can write down an equation which tells how the energy content of a particular wave component changes in time as it travels. The right hand side of this equation contains energy input from the wind, energy dissipation from waves breaking and bottom dissipation. To derive the bottom dissipation term we use our relationship among wave and sediment characteristics to predict the resulting bottom roughness. We can then say how the energy content of each wave component changes with time and distance traveled, thereby predicting the change in the wave spectrum resulting from bottom dissipation," explains Madsen.



x, for constant f_w = 0.02 and variable f_w. Water depth = 100 m at x = 0, 15 m at x = 100 km. Initial wave height = 8 m, period 10s, sediment diameter = 0.15 mm.

Figure 3. Significant wave height vs. shoaling distance for Constant f_W and Variable f_W.

Since the resulting bottom roughness depends on the wave-sediment interaction, the calculations involve a constant update of the predicted bottom roughness as the wave spectrum alters. Madsen is convinced that bottom friction becomes a very important factor in terms of dissipating wave energy in shallow water.

Madsen and student Hans Graber want to incorporate their bottom roughness relationship into a dissipation model fitted to mesh with a wave prediction model by Professor Klaus Hasselmann at the University of Hamburg, Germany. They want to reformulate their theoretical model, which has experimental backing for the flow near the bed to take into account the randomness of wind waves. The relationship between bottom roughness and motion and the associated friction factor will be different in a random sea, as opposed to a lab wave tank. "Wave-sediment interaction, bottom roughness and corresponding energy dissipation and friction factor, show how a particular wave spectrum will change in time."

So far, Madsen feels that they have a good relationship for the friction, for the attenuation and dissipation of energy, and for the ripple geometry of the bed for laboratory waves. The next step will be to either associate randomly generated laboratory waves with bottom roughness or ripple geometry, or even better, to use field data to test the validity of the present model.

On Georges Bank, where oil drilling will occur in shallow water, storm waves will be severely affected by bottom friction. A more sophisticated model for wave prediction could give a much better idea of what magnitude waves will hit offshore structures.

MIT Sea Grant Publications

Instead of the new-release abstract form that usually accompanies the *Quarterly Report*, we have enclosed a complete directory for all MIT Sea Grant reports published between January 1980 and March 1981. Most of the reports have been described in previous *Quarterlies*, while those introduced for the first time are highlighted in the following list. All reports are available through the MIT Sea Grant Program, Massachusetts Institute of Technology, Building E38-302, Cambridge, MA 02139.

Mechanics of a Restrained Layer of Floating Oil Above a Water Current.
Jerome H. Milgram and Robert J. Van Houten. MITSG 80-4J. 16pp. $1.00.

This paper determines the relative importance of interfacial shear stress and dynamic pressure in determining the thickness distribution of a layer of floating oil contained by a barrier above a water current. An equation is discussed relating vertical location of the oil-water interface, dynamic pressure, and shear stress. Reprinted from: *J. Hydronautics*, 12(3), July 1978.

MIT Sea Grant: Ten Years of Ocean Development.
A Report on the Massachusetts Institute of Technology Sea Grant College Program 1970-1980. MITSG 80-15. 80 pp. No charge.

This report takes an abbreviated look at Sea Grant's ten program years at the Institute. Summaries of publications, projects, participants, and expenditures focus specifically at the 1979-1980 program year.

Effects of Temperature Conditioning on Development and Germination of Gonyaulax tamarensis (Dinophyceae) Hypnozygotes.
Donald M. Anderson. MITSG 80-16J. 7 pp. $1.00.

Laboratory studies to account for spring and fall red tides examined two growth stages of *Gonyaulax tamarensis:* intermediate planozygotes, which then form hypnozygotes, dormant "seeds." Comparisons of spring and fall hypnozygote formation and temperature conditions are explored. Reprinted from: *J. Phycol.* 16, 1980.

The Oil Spill Incidence Simulation Model: Description and User's Manual.
Ludwik J. Kondratowicz and Harilaos N. Psaraftis. MITSG 80-17. 72 pp. $3.50

The Oil Spill Incidence Simulation Model simulates random spill incidents of different oil types occurring at various locations from different sources, during a *specified period*. Regional and probabilistic data can be incorporated into the program, and the strategic time scale of events, on the order of months or years, can be adjusted to operate on a real-time, tactical basis.

National Response Capability To Oil Spills: A Systems Approach.
Harilaos N. Psaraftis, Andrew V. Baird, J.D. Nyhart. MITSG 80-18J. 8 pp. $1.00.

This paper describes a systems approach for the formulation of the overall problem of oil spill pollution response in the United States. The paper discusses objectives of existing and alternative systems for oil spill response, and provides a hierarchical decision framework for optimal oil spill response at strategic, tactical and operational levels. Financial and damage assessments are also presented. Reprinted from Oceans '80.

Geotechnical Reliability of Offshore Gravity Platforms.
Gregory B. Baecher, Mark Chan, Thomas S. Ingra, Thomas Lee, Louis A. Nucci. MITSG 80-20. 293 pp. $8.00

Current techniques of risk and reliability analysis provide a strong analytical framework for handling many offshore design uncertainties. This report describes existing methods and combines them into a unified analytical approach. An important part of the study discusses the uncertainties introduced by modeling and the relationship of those uncertainties to parameter estimation.

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The MIT Sea Grant *Quarterly Report* reviews the Programs's marine-related activities at the Massachusetts Institute of Technology. Free subscriptions are available on request from the MIT Sea Grant College Program, Building E38-302, Cambridge, MA 02139. Telephone: (617) 253-3461.

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MIT Sea Grant Publications
January 1980-March 1981

Publications

Research

Fisheries and Living Resources

1 The Design, Construction and Development of a Prototype Machine for Processing Spiny Dogfish Shark. William B. Hoff, III and David Gordon Wilson. MITSG 80-14. 58 pp. $3.50.

New food sources require new technology. An example is this advanced prototype machine, with pneumatically actuated parts and a solid-state, programmable controller, for processing the spiny dogfish shark. The process follows the steps used by hand labor, but cuts in half the time required to process a fish, to approximately 12 seconds. With simple developments in future machines, the time could be considerably reduced.

2 Effects of Temperature Conditioning on Development and Germination of Gonyaulax Tamarensis (Dinophyceae) Hypnozygotes. Donald M. Anderson. MITSG 80-16J. 7 pp. $1.00. NTIS: PB81 134876.

Laboratory studies to account for spring and fall red tides examined two growth stages of Gonyaulax tamarensis: intermediate planozygotes, which then form hypnozygotes, dormant "seeds." Comparison of spring and fall hypnozygote formation and temperature conditions found hypnozygotes formed in cold water bloom when water temperature increases; those formed in warmer water bloom when temperature decreases. Observed starch decrease in hypnozygotes and mucilagenous excretions need further study. Reprinted from: J. Phycol. 16, 1980.

Ocean Engineering

3 An Assessment of Undersea Teleoperators. Thomas N. Sofyanos and Thomas B. Sheridan. MITSG 80-11. 315 pp. $8.00 NTIS: PB81 102535.

This Mechanical Engineering Department thesis assesses undersea teleoperators and competing methods of underwater intervention. The report examines general purpose, remotely controlled work vehicles and discusses representative costs for offshore divers and manned and unmanned submersibles. The role of remotely operated vehicle systems in offshore installation inspection, development trends for teleoperator systems, and federally supported programs are evaluated.

4 Experiments in Supervisory Control of a Computerized Vehicle for Inspecting Curved Surfaces. Tetsuichi Odahara and Thomas B. Sheridan. MITSG 80-19. 77 pp. $4.00.

Graduate research in underwater work vehicle support systems has developed a computerized vehicle for inspecting curved surfaces, such as pipelines. The control system uses three kinds of vehicle motion control: manual, automatic approaching, and automatic surface following. The report documents manual control difficulties and the advantage of combined manual and automatic control systems and considers the adaptability of supervisory control concepts to undersea inspection.

Ocean Engineering-Offshore Structures

5 Prediction of the Damping-Controlled Response of Offshore Structures to Random Wave Excitation. J. Kim Vandiver. MITSG 80-9J. 10 pp. $1.00.

This paper introduces a simple procedure for estimating a structure's dynamic response at each of its natural frequencies to random wave excitation. For many structures, a simple expression may be derived for the wave force spectrum in terms of radiation damping and the prescribed wave amplitude spectrum. In this method explicit calculation of wave forces is not required. Example calculations are presented. Reprinted from: Soc. of Pet. Engineers J., 1980.

6 Pore Pressures During Cone Penetration in Clays. Jacques-Noel Levadoux and Mohsen M. Baligh. MITSG 80-12. 310 pp. $8.00.

In situ and laboratory analyses of cone penetration and pore pressure estimation in clays are discussed. Test results are combined with special soil behavior models and known soil element strain paths which determine deviatoric stresses and sheer-induced pore pressures. The comparisons attempt to explain test differences in different deposits and apply questions about soil stability and compressibility with deep penetration, pile installation, and undrained loading problems in offshore construction.

7 Pore Pressure Dissipation After Cone Penetration. Mohsen M. Baligh and Jacques-Noel Levadoux. MITSG 80-13. 368 pp. $8.00. NTIS: PB81 102485.

This report describes rapid response conical piezometers used to evolve new analytical methods of determining soil properties directly at offshore sites. The methods of estimating consolidation and permeability characteristics of clays from measurements of the pore pressure decay after cone penetration is interrupted are evaluated, using extensive dissipation measurements in two clay deposits. The predicted profiles provide good agreement with laboratory data and full-scale performance.

8 Cone Penetration Tests Offshore The Venezuelan Coast. Mohsen M. Baligh and Amr S. Azzouz. MITSG 80-21. 164 pp. $8.00.

One of a series, this report publishes further results of a soils testing program offshore Venezuela using a Dutch cone and pore pressure probe. Theoretical and empirical correlation procedures, and information about in situ undrained stress-strain-strength behavior in test sites and in known characteristic soils were compared. Researchers developed theoretical models for interpreting cone penetration and pore pressure data, with guidelines for using cone penetrometers to estimate in situ properties for foundation design.

9 Geotechnical Reliability of Offshore Gravity Platforms. Gregory B. Baecher, Mark Chan, Thomas S. Ingra, Thomas Lee, Louis A. Nucci. MITSG 80-20. 271 pp. $8.00.

Current techniques of risk and reliability analysis provide a strong analytical framework for handling many offshore design uncertainties rationally. This report describes existing methods and combines them into a unified analytical approach. An important part of the study discusses the uncertainties introduced by modeling and the relationship of those uncertainties to parameter estimation.

Pollution Control

10 The Oil Spill Incidence Simulation Model: Description and User's Manual. MITSG 80-17. Ludwik J. Kondratowicz and Harilaos N. Psaraftis. 72 pp. $3.50.

A component of an oil spill computer modeling project, SIMSPIL, the Oil Spill Incidence Simulation Model, simulates random spill incidents of different oil types occurring at various locations from different sources, during a specified period. Regional probabilistic data can be incorporated into the program, and the strategic time scale of events, on the order of months or years, can be adjusted to operate on a real-time, tactical basis.

11 National Response Capability to Oil Spills: A Systems Approach. Harilaos N. Psaraftis, Andrew V. Baird, J.D. Nyhart. MITSG 80-18J. 8 pp. $1.00.

This paper describes a systems approach for the formulation of the overall problem of oil spill pollution response in the United States. The paper discusses objectives of existing and alternative systems for oil spill response, and provides a hierarchical decision framework for optimal oil spill response at strategic, tactical and operational levels. Financial and damage assessments are also presented. Reprinted from: Oceans 80.

12 Mechanics of a Restrained Layer of Floating Oil Above a Water Current. Jerome H. Milgram and Robert J. Van Houten. MITSG 80-4J. 16 pp. $1.00. NTIS: PB80 187214.

This paper determines the relative importance of interfacial shear stress and dynamic pressure in determining the thickness distribution of a layer of floating oil contained by a barrier above a water current, using an equation relating vertical location of the oil-water interface, dynamic pressure, and shear stress.

Forward and rear portions of the oil layer relative to wave direction are studied at both low and higher current speeds. Reprinted from: J. Hydronautics, 12(3), July 1978.

Advisory Services

13 Understanding the Oceans. Motivating Today's Youth to Work for Tomorrow. Eighth Annual Sea Grant Lecture. Herman R. Branson, James W. Mayo, Mary P. Rowe, Logan H. Sallada, Roderick M. White. MITSG 80-1. 24 pp. No charge. NTIS: PB80 182165.

In the Eighth Annual Sea Grant Lecture and Symposium, Dr. Herman R. Branson, scientist, educator, and president of Lincoln University since 1970, discussed helping women and minorities to overcome existing impediments to marine-related careers. Panelists included Dr. Mary P. Rowe, MIT; Dean Roderick M. White, U.S. Coast Guard Academy; Dr. James W. Mayo, Department of Energy; Mr. Logan Sallada, Human Resources Division, Office of Management and Budget.

14 Georges Bank: Fish and Fuel. Ninth Annual Sea Grant Lecture. Ronald C. Lassiter, Morris A. Adelman, Douglas I. Foy, Paul M. Jacobs, and Don E. Kash. MITSG 81-1. 40 pp. No charge.

This year's lecturer, Ronald C. Lassiter, president of Zapata Corporation, examined objections to oil drilling on Georges Bank. Panelists debating how the petroleum and fishing industries can resolve their differences included Morris A. Adelman, Professor of Economics, MIT; Douglas I. Foy, Executive Director, Conservation Law Foundation; Paul M. Jacobs, Managing Partner, Basic Development Services; and Don E. Kash, Chief, Conservation Division, U.S. Geological Survey.

15 Directory of MIT Sea Grant College Program Publications 1978-1979. MITSG 80-3. 32 pp. No charge. NTIS: PB 80 186620.

All MIT Sea Grant Program education, advisory, and research publications for the years 1978 and 1979, including 4 slide-tape presentations, are covered in this publications directory. Each is described in a brief abstract, and price and ordering information is given. Also included are author, publication number, and subject and title indexes. This volume complements MITSG 78-6, a directory listing all MIT Sea Grant Program publications for 1970-1977.

16 Marine-Related Research at MIT 1980. Compiled by Barbara Steen-Elton. MITSG 80-10. 57 pp. No charge.

All marine research at MIT, including that sponsored by the National Sea Grant Program, is listed in this annual directory by topic: Coastal Zone Ecology, Management, and Coastal Processes; Education; Energy; Fisheries and Living Resources; Marine Mineral Resources; Ocean Engineering Acoustics, Hydrodynamics, Instrumentation, Materials, Offshore Structures, Ship Structures; Oceanography, Marine Chemistry, Marine Geology, Physical Oceanography; Pollution; Transportation; and Water Resources. Includes subject and author/principal investigator indexes.

Marine Industry Advisory Service – MIDAS

17 Some Federally Sponsored Research Programs for Unmanned Underwater Vehicles. Opportunity Brief #18. MIT/Marine Industry Collegium. MITSG 80-5. 34 pp. $3.50.

With mention of telemanipulators and supervisory control theory, this Opportunity Brief reviews unmanned underwater vehicle research: MIT's untethered search and survey vehicle; the Naval Ocean Systems Center's free-swimming submersible using direct and supervisory control; and the University of New Hampshire experimental autonomous vehicle with five degrees of freedom of motion, developed by UNH, NOSC, and the U.S. Coast Guard. Appendices introduce the Naval Research Lab laminar flow vehicle and questionnaire results on future work vessel capability needs.

18 A New Underwater Communication System. Opportunity Brief #19. MIT/Marine Industry Collegium. MITSG 80-6. 17 pp. $3.50.

This Opportunity Brief presents a joint acoustical telemetry communications project for untethered underwater work vehicles at MIT and Woods Hole Oceanographic Institution. Because of microprocessor advances, the system of transforming digital data to "chords" can be adapted through programmable software changes and satisfy a variety of uses requiring trade-offs among key parameters of data rate, range, and error rates.

19 Protection of Materials in the Marine Environment. Opportunity Brief #20. MIT/Marine Industry Collegium. MITSG 80-7. 9 pp. $3.50

A collaborative presentation of the Sea Grant programs of Louisiana State University (LSU) and MIT, this Opportunity Brief discusses aspects of LSU marine materials protection research: longlasting antifouling marine coatings, characterization and environmental impact; hydrogen embrittlement, including cathodic protection concentration of environmental hydrogen; and titanium-based metallic coatings. Also discussed are two LSU projects: remote sensing and interpretation of data with a TIROS satellite, and creative computer-aided ship design tools.

20 Nondestructive Evaluation of Fiber Composites. Opportunity Brief #21. MIT/Marine Industry Collegium. MITSG 80-8. 20 pp. $3.50.

Inherently nonhomogeneous, fiber composites can contain hard-to-detect internal flaws. A process of nondestructive thermal testing for flaws involves coating the material with a cholesteric liquid crystal compound. Applying heat causes the crystals to change color, and anomalies in color indicate internal flaws. This project provides quantitative interpretation of surface temperature patterns and underlying flaws, and mentions acoustic and ultrasonic testing.

Program Management

21 A Report on the Massachusetts Institute of Technology Sea Grant College Program: 1 July 1978 to 30 June 1979. MITSG 80-2. 48 pp. No charge. NTIS: PB80 183718.

In the MIT Sea Grant College Program annual report for 1978-1979, project summaries define Sea Grant's research in coastal and ocean resource uses and show how advisory plans help transfer information to the public. Descriptions of the Program's education projects illustrate efforts to train and inspire a marine literate citizenry. Fiscal summaries and listing of publications, participants and contributors, and Sea Grant's staff are included.

22 MIT Sea Grant: Ten Years of Ocean Development. A Report on the Massachusetts Institute of Technology Sea Grant College Program 1970-1980. MITSG 80-15. 80 pp. No charge.

Congress established the National Sea Grant Program in 1966 to coordinate development and use of marine and coastal resources. This report takes an abbreviated look at Sea Grant's ten years at the Institute. A sampling of projects illustrates how all segments of the community can cooperate to solve marine-related problems and take advantage of industrial opportunities. Summaries of publications, projects, participants, and expenditures look specifically at the 1979-1980 program year.

Report Number Index

Ordering Information

These reports are available from: MIT Sea Grant College Program, E38-302, Massachusetts Institute of Technology, Cambridge, MA 02139. The price listed includes the cost of printing, handling, and fourth class mailing. Please refer to the "MITSG" number when ordering.

Reports listed with an "NTIS" number are also available from the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161. Prices are subject to change.

Publications directories for the MIT Sea Grant Program 1970-1979 are available upon request.