ENGINEERING CONSIDERATIONS FOR MARINAS IN TIDAL MARSHES

by Steven P. Giannio and Hsiang Wang

This work is a result of research supported by the Department of Civil Engineering, University of Delaware. Publication of this report is supported by NOAA, Department of Commerce, under Grant No. 04-3158-30.

DEL-SG-9-74

November, 1974

College of Marine Studies
University of Delaware
Newark, Delaware
19711

ACKNOWLEDGMENT

This research work was partially supported by a NDEA fellowship awarded to the senior author through the Department of Civil Engineering. Members of the Ocean Engineering Group of the faculty of the Department of Civil Engineering have rendered their assistance in gathering material.

TABLE OF CONTENTS

LIST OF TABLES & FIGURES

		Page
Table 19	Major Coastal Metropolitan Areas Around Estuaries	66
Figure 13	Flowing River Canal System With One-Way Valve Cross-Section	71
Figure 14	Channel Protection Designs	75
Figure 15	Marsh Location for Marina Development	87
Table 20	A) Berth Requirements by Size & Number B) Minimum Dimensions for Berths & Slips	89
Figure 16	Layout for Berths and Slips	90
Figure 17	Marina Development in Former Marsh	92
Figure 18	Section Through Channel Rip-Rap Protection	97

ABSTRACT

The problem addressed by this report is how to design a small boat marina at a tidal marsh site with minimum adverse environmental impact on the estuarine-marsh ecosystem.

In many estuarine systems the tidal marsh is the principal source of organic food production upon which all estuarine species depend. Yet, these same marshes may be the only remaining tracts of undeveloped land in densely populated urban-suburban regions. When the need arises for new marine recreation facilities in these urban areas, a conflict between the ecological importance of untouched marshlands and progressive development can only be resolved through innovative engineering practices.

In this report, design guidelines have been developed to incorporate the desirable qualities of the marsh in a marina, thereby reducing the environmental impact. When a marina displaces marshland, the most important quality which must be maintained is biological production. The methods suggested and recommended for the preservation of this quality are:

- flush the marina to promote water circulation which cycles nutrients and prevents eutrophication

- use dredge spoils from the marsh to establish new productive marshes elsewhere
- provide contact area within the marina so fouling communities, an organic food source, can prosper and multiply
- control water quality so that estuarine species can thrive in the marina
- provide an equal amount of organic food in the marina to make up for the loss of food from displaced marshland.

To indicate how a complementary marina-marsh system could be achieved, an example of a composite design using these guidelines is also presented.

CHAPTER 1

INTRODUCTION

The tidal marshlands of this nation are the subject of constant conflict regarding their utilization in man's relentless expansion. Society views them as desolate wastes of mud, grass and insects, uninhabitable, and therefore worthless, an area that should be dug up, paved over or otherwise altered for man's uses, whereas a different view is taken by those who see any encroachment on remaining undeveloped lands as a threat to wildlife and fisheries resources. They resist unplanned developments that would alter the esthetic beauty of the land and disturb its balance with nature.

An optimum solution for the utilization of marshland cannot lie at either of these two extremes of view. Instead, man-made developments in their design should be planned to preserve the natural elements of the marshland. This would minimize the disturbance of the development on the surrounding environment while creating new areas for expansion.

The National Environmental Policy Act of 1966 requires that all new water resources projects submit an Environmental Impact Statement before they can be approved by the government for construction. The main thrust of this act is to encourage greater harmony between man and his environment and to protect the environment for the overall welfare of man.[4] An optimum solution for marshland development, therefore, is one which provides the least possible environmental impact.

The possible uses of newly developed land in marshes are industrial, urban, and recreational. Of these, marine recreational facilities, especially marinas, are the most dependent upon a land water interface and the least disturbing to the environment. This report attempts to find an optimum solution for a marina development on a marsh site.

The method of approach is to first explain what is important about the marsh as a natural system; then to show how man-made changes have affected the system in the past. These two approaches tell us what should be preserved and which changes should be avoided in the new marina development. Once it has been established that new marina facilities are necessary, we use the information gathered in the previous sections to indicate what problems will be encountered when converting a marsh to a marina with minimum environmental impact. The solutions to these individual problems collectively comprise the optimum solution which maintains the desirable properties of a marsh within the bounds of a new marina development. Therefore, the main objective of this study is to set up guidelines to achieve this purpose.

CHAPTER 2

ECONOMIC AND SOCIAL VALUE OF ESTUARINE ZONE

"The estuarine zone is an environmental system consisting of the estuary and all adjacent transitional areas whose environments are consistently influenced by the physical and/or ecological nature of the estuary."[20] This zone includes areas such as the shorelines surrounding the estuary, salt meadows and coastal marshes adjacent to the estuary, intertidal areas, and fresh water habitats above the upper limit of salt water intrusion.

The estuarine zone, like other valuable natural resources in this country, has suffered considerable damage in the past because of unplanned development by uninformed man. Such damages can be avoided if the value of the estuarine zone to man is understood. Therefore, the emphasis of this chapter is to demonstrate the valuable functions served by the estuaries so that they may be preserved in any subsequent developments.

2.1 Biological Production in the Tidal Marsh

In many estuaries, the primary organic productive units are phytoplankton, benthic algae, and marsh grasses.[4] Phytoplankton are concentrated in open water areas, whereas benthic algae and marsh grasses are associated with intertidal lands.

Algae may be found on the surface of mud exposed at high tide; on the surface of lower parts of grass stalks; growing on any solid surface wet regularly by the tides; or as floating algae, living in the water, continually entering and leaving the marsh with the tides.[15] Algae production continues throughout the year in the northernmost and southernmost marshes of the country.

In contrast, Spartina, the dominant marsh grass, grows to some extent throughout the year only in southernmost marshes. In northern marshes, Spartina grows only during the warmer parts of the year. When the grass dies for any reason such as maturation, freezing, trampling or washouts, it can no longer protect itself from bacteria which immediately begin to decompose the grass. The bacteria reduce the grass to organic detritus which then becomes available as a source of food for many animals which are not equipped to eat Spartina's cellulose structure.[15]

The tides are the fertilizing agent in the marshes. The mixing of fresh and salt water by winds and tides results in efficient vertical mixing, and creates an ideal environment for oxidizing and removing organic wastes and for cycling nutrients in the form of an algae-detritus 'soup' interspersed with mud, water and the multitudes of organisms associated with and dependent upon this ecosystem.[4]

If production were to be expressed in weight, the salt marsh is a luxuriant producer. Georgia's Spartina marshes produce five to nine tons of plant material an acre a year; Virginia's, three and Delaware's, two.[9] On the average the salt marsh produces between five and ten tons of organic matter per acre per year. Compare this to the best hay lands in this country which produce four tons per acre per year, or to Europe's best wheat land which yields seven tons per acre per year.[15] About half of all this marsh production flows into estuaries to nourish the animals of the sea.[9]

When a developer destroys the marshes and intertidal lands, marsh life is cut off at its source in the primary food production of its grasses and algae. Some marsh animals graze directly on the marsh grass, many more feed on the detritus-algae soup, and others feed on the feeders, but all depend upon the marsh environment for food and shelter.

2.2 Commercial Fisheries

In addition to their high biological productivity, the tidal marshes serve as nursery and feeding grounds for the young of many of our most important species of fish and shellfish. These species are called 'estuarine dependent' and are divided into the following categories.[20]

Resident species - Sessile forms that spend their entire life cycle in estuarine waters, e.g., oysters, clams, blue crabs

Semicatadromous species - Spawn in the ocean but their young migrate to the estuarine nursery where they grow to subadults, returning to the ocean for adult stage, e.g., shrimp, menhaden

Anadromous species - Spawn in fresh or brackish waters; the young migrate through the estuary to the ocean where growth and development are completed. Adults must return through the estuary to spawning grounds, e.g., salmon, striped bass

Other types of commercially valuable fish such as tuna, perch, and haddock may be indirectly dependent upon nutrients and food chains linked with estuarine areas, but present knowledge makes this doubtful.

The importance of estuarine-dependent species to the United States commercial fisheries landings can be shown by Table 1. It gives the 1966 landings in the United States by region, together

TABLE 1 COMMERCIAL FISH LANDINGS FROM UNITED STATES WATERS, 1966

Region[1]	Total Landings[2/] Millions of pounds	Estuarine-dependent Landings[2/] Millions of pounds	Percent Estuarine-dependent
North Atlantic	611	43	7
Middle Atlantic	241	128	53
Chesapeake Bay	502	493	98
South Atlantic	368	350	95
Gulf of Mexico	1,196	1,149	96
South Pacific	1,214	515	42
North Pacific	251	145	53
Alaska	582	386	66
Hawaii	13	3/	1
Great Lakes	68	68	100
Totals	5,046	3,277	65

1/ The landings for the Biscayne and Florida Bay Estuarine Region are not separated from the South Atlantic and Gulf of Mexico landings.

2/ Includes finfish and shellfish

3/ Only 0.14 million pounds

REFERENCE: No.18 Page 116

with the proportional composition of the catch. In the nation, the estuarine-dependent species comprise 65 percent by weight of the total landings.

Table 2 gives the 1967 landings in the United States by weight and value of the 25 most important commercial fish and shellfish with an indication of their dependence upon estuaries. It shows that 72 percent by weight and 71 percent by value of the 1967 catch were estuarine-dependent species.

The annual landed value of the United States catch is 475 million dollars of which 75 percent or 300 million is estuarine-dependent or associated kinds.[20] This underestimates the value of the industry to the national and regional economies because the harvesting segment of the industry is small compared to the economic activity generated by the processing, transportation, and marketing segments of the industry. The final market value of the catch is 1.5 billion dollars annually of which 1.1 billion is estuarine-dependent.[20]

There is also the possibility of reviving the fishing industry to compensate for losses of naturally productive estuarine areas by the use of aquaculture. This is the artificial production of selected species in a controlled estuarine environment. Through research this may become an important technique for increasing production in the future.

TABLE 2: The First-Ranked 25 Kinds of Commercial Fish and Shellfish Landed in the United States in 1967, by weight and value with Notations and Summaries of Estuarine-Dependent and Associated Kinds.

Kind	Weight Mil. lbs.[1/]	Est.[2/]		Value Mil. dol.	Est.[2/]
Menhaden	1,164	X	Shrimp	103	X
Tuna	328		Salmon	49	X
Crabs			Tuna	44	
King	128		Crabs		
Other	187	X	King	15	
Shrimp	308	X	Other	15	X
Salmon	218	X	Oysters	32	X
Industr. Fish	212	X	Lobsters, North	22	X
Flounders	159	X	Clams	20	X
Alewives	101	X	Flounders	17	X
Haddock	98		Menhaden	14	X
Herring, sea	88	X	Haddock	11	
Clams	72	X	Scallops, sea	8	
Ocean Perch	71		Catfish	7	
Anchovies	70		Halibut	6	
Whiting	70		Snapper, red	4	
Oysters	60	X	Cod	4	
Cod	54		Scup or progy	3	X
Halibut	40		Industr. Fish	3	X
Jack Mackerel	38		Lobster, spiny	3	
Mullet	34	X	Ocean Perch	3	
Catfish	33		Mullet	2	X
Carp	32		Buffalofish	2	
Hake	29		Whiting	2	
Lobster, North.	27	X	Mackerels	2	
Mackerels	24		Herring, sea	2	X
Squid	23		Chubs	2	
Grand Totals:	3,668			395	
Est. Totals[2/]	2,630			282	
Percent Estuarine	72			71	

[1/] Round weight except clams and oysters which are meats only

[2/] Estuarine-dependent and associated kinds.

REFERENCE: No.18 Page 117

The heavy preponderance of estuarine-dependent species in United States commercial fish landings is evidence that our estuarine zones, especially the food-producing marshes, must be carefully protected against destructive uses. It has been estimated that by the year 2000 demand for fishery products will more than double.[18] The percentage of these fish caught in U.S. waters, rather than imported, will depend heavily upon our care of the estuaries.

2.3 Recreation

Projections indicate a rapid increase in the demand for marine-orientated recreation facilities in the future. This demand will result primarily from three important factors:[20]

1. The population of the United States is expected to increase from 205 million in 1970 to 400 million in 2020 and in the estuarine zone it will increase from 60 million in 1960 to 139 million in 2020;
2. Both disposable personal income and the percentage of personal income spent on recreation will continue to increase; and
3. Leisure time will increase significantly as longer vacations and shorter workdays and workweeks become more prevalent.

Tables 3 and 4 indicate increased participation and annual expenditures for some marine recreation activities. Recreation is a large important business in the estuarine zone in that improved facilities stimulate sales in equipment, food, and lodging, and create new jobs.

Sport fishing, an important economic recreation activity, is related to estuaries in the following ways:[20]

1. a majority of species caught rely on estuaries for some phase of their life cycle;

TABLE 3: OCCASIONS OF PARTICIPATION IN OUTDOOR RECREATION IN UNITED STATES

	Participation (in millions)			% Increase
	1965	1980	2000	1965-2000
Swimming	970	1,671	2,982	207
Fishing	322	422	574	78
Boating	220	386	694	215
Water Skiing	56	121	259	363

TABLE 4: ECONOMIC ACTIVITY IN COASTAL AND OFFSHORE AREAS

	Annual Expenditures in U.S. (Millions of Dollars)	
	1964	1975
Swimming	1,500	2,000
Fishing	760	1,300
Boating	650	1,000
National Parks & Forests	600	1,390

REFERENCE: No.20 Page 50, Appendix F

Source: Commission on Marine Science, Engineering & Resources: "Marine Resources and legal-political arrangements for their development, panel report, Vol. 3" U.S. Government Printing Office, Feb. 9, 1969, Page VII - 237,239

2. land-based activities usually occur from docks, piers, bridges, etc. located in estuaries; and
3. sport fishing vessels generally depend upon estuary-based facilities for mooring and service requirements.

In a 1965 Saltwater Angling Survey conducted by the Bureau of Census for the Bureau of Sport Fisheries and Wildlife, it was estimated that 4.132 million fisherman fished in sounds, tidal rivers, and bays (i.e., the estuarine zone) and 4.21 million fished in the ocean.[18] Most fish sought by ocean fisherman are estuarine-dependent, so the total number may be counted, more or less, as estuarine zone users.

Hunting activities are limited almost completely to waterfowl in the estuarine zone. The general trend is that estuarine hunting is slowly decreasing due to increased urban and industrial activity in the zone which has progressively destroyed natural habitats with resultant reduction in waterfowl populations.

Swimming, Surfing, and Skin Diving

It has been estimated that participation for these contact sports in the estuarine zone accounts for less than three percent of the national total.[20] The reasons for this low participation are: generally poor or prohibitive water quality in estuaries due to pollution; poor beaches and surf on estuarine shorelines; and frequent lack of access to the water due to marshy terrain or blockage by private development. Despite these limitations, these activities have the highest rate of participation of any major estuarine activity.

Boating

Recreational demand for boating will increase sharply in the future. This increase is partially dependent upon the increase in demand for fishing, skin diving, and water skiing which require boating for their completion. Chapter 4 deals with recreational boating demand in detail.

2.4 Waterborne Commerce

"The economic health of the United States is to a significant degree related directly to a port and shipping industry that can rapidly, safely, and inexpensively transfer imports, exports, and domestic trade between terminal points."[6] The economic activity generated by the network of U.S. ocean ports strengthens all phases of the national industrial and market structure.

To see the dependence of this commerce on the estuaries, a survey in 1965 by the Maritime Administration showed that 1,626 marine terminals in 132 estuarine ports on the Atlantic, Gulf, and Pacific coasts handled 346.3 million tons of foreign trade cargo, which represents 78 percent of the total U.S. foreign trade or 90 percent of all coastal ports foreign trade.[6] Table 5 shows the distribution of estuarine ports by coast and state.

Projections by the Department of Transportation indicate that the foreign sector of waterborne commerce will increase significantly in the next 10 to 30 years from a total trade of 440 million short tons in 1970 to over 1400 million short tons by the end of the century.[20] Due to a revolution in ship cargo operations, much of this new trade will be carried in larger vessels with deeper drafts and by container ships. (See Table 6 for projected vessel characteristics, 1970-2000). These new vessel characteristics will require estuarine ports to alter their berthing areas and update their shore facilities if they wish to maintain their place in national commerce.

TABLE 5: DISTRIBUTION OF ESTUARINE PORTS
BY COAST AND BY STATE

Coast	State	Number of Ports	Number of Terminals
Atlantic	Maine	3	18
	New Hampshire	1	5
	Massachusetts	6	77
	Rhode Island	1	19
	Connecticut	3	13
	New York (a)	1	294
	New Jersey	8	18
	Delaware	2	4
	Pennsylvania	4	71
	Maryland	1	89
	Virginia	4	68
	North Carolina	2	23
	South Carolina	3	21
	Georgia	2	23
	Florida	6	45
Gulf	Florida	7	48
	Alabama	1	29
	Mississippi	2	7
	Louisiana	3	105
	Texas	10	157
Pacific	California	19	222
	Oregon	8	68
	Washington	11	132
	Alaska	15	29
	Hawaii	9	41

(a) includes 36 terminals located in New Jersey

REFERENCE: No.6 Page D-3

Source: Department of the Army, Corps of Engineers

TABLE 6: PROJECTED VESSEL CHARACTERISTICS 1970-2000

	1970	1980	1990	2000
Freighters				
Maximum DWT in world fleet	25,500	33,500	43,500	50,000
Length (feet)	850	930	1,010	1,050
Beam (feet)	108	117	127	132
Depth (feet)	74	80	85	88
Draft (feet)	36	39	40	40
Average DWT in world fleet	8,168	8,583	9,043	9,350
Bulk Carriers				
Maximum DWT in world fleet	105,000	185,000	317,000	400,000[1]
Length (feet)	870	1,040	1,230	1,325
Beam (feet)	125	152	183	198
Depth (feet)	71	84	99	106
Draft (feet)	48	57	66	71
Average DWT in world fleet	14,750	18,750	25,575	27,350
Tankers				
Maximum DWT in world fleet	300,000	760,000	1,000,000[1]	1,000,000[1]
Length (feet)	1,135	1,460	1,570	1,570
Beam (feet)	186	252	276	276
Depth (feet)	94	129	142	142
Draft (feet)	72	98	104	104
Average DWT in world fleet	39,825	76,225		94,325

[1] Uppermost practical limit, based upon projected technology and experience.

REFERENCE: No.20 Page 11, Appendix F

Source: Commission on Marine Science, Engineering, and Resources: "Science and Environment, Panel Report Vol. 1" U.S. Government Printing Office, Feb. 9, 1969

2.5 Water Resources

Uses for water resources in the estuarine zone are: as a vital traffic artery for ocean shipping; a harbor of refuge for all types of watercraft; coolant water for municipal, industrial and nuclear power plants; a source of fresh water through desalination facilities; effluent disposal for municipal and industrial wastes; and cheap solid waste disposal sites.

Clearly, some of these uses are destructive rather than complementary to the estuarine system. Yet if one ignores their destructive nature, an economic value can be attached to the water resources used. For instance, Table 9 illustrates the economic contribution of sample estuaries for incremental secondary treatment of wastes. For the combined estuaries a total of 5.9 million dollars per year is the estimated economic contribution of estuarine assimilative capacity per milligram per liter of dissolved oxygen.

The significance of this figure is that this would be the cost to provide incremental secondary treatment to industrial and municipal wastes if the estuaries no longer had the capacity to assimilate them. It is therefore in our best economic interest to protect and maintain high water quality in the estuaries so that they can assimilate wastes and help pay part of our nation's waste treatment bill. (The economic contribution in Table 9 is arrived at by multiplying the cost for incremental secondary treatment - 0.04 dollars/pound BOD removed, Table 7 by the BOD removal required to

TABLE 7: APPROXIMATE COSTS OF WASTE TREATMENT

Type of Treatment	Approximate	
	Dollars/Million Gallons Treated	Dollars/Pound of BOD Removed
Primary	90	0.150
Secondary	130	0.080
Incremental secondary	40	0.040
Incremental tertiary	150	2.00

TABLE 8: BOD REMOVALS REQUIRED TO ACHIEVE 1 MG/ℓ INCREASE IN MINIMUM DISSOLVED OXYGEN

Estuary	BOD Removal, lb/day
Delaware	100,000
Potomac	28,000
James	39,000
East	51,000
Hudson	187,000

TABLE 9: ECONOMIC CONTRIBUTION OF ESTUARINE ASSIMILATIVE CAPACITY PER MG/ℓ OF DISSOLVED OXYGEN

Estuary	Economic Contribution		Surface Area, acres
	dollars/day	dollars/year	
Delaware	4000	1,460,000	70,500
Potomac	1120	408,000	17,000
James	1560	570,000	5,120
East	2040	745,000	18,800
Hudson	7450	2,720,000	5,250
	TOTAL	5,903,000	116,670

REFERENCE: No. 6 Pages 621-22

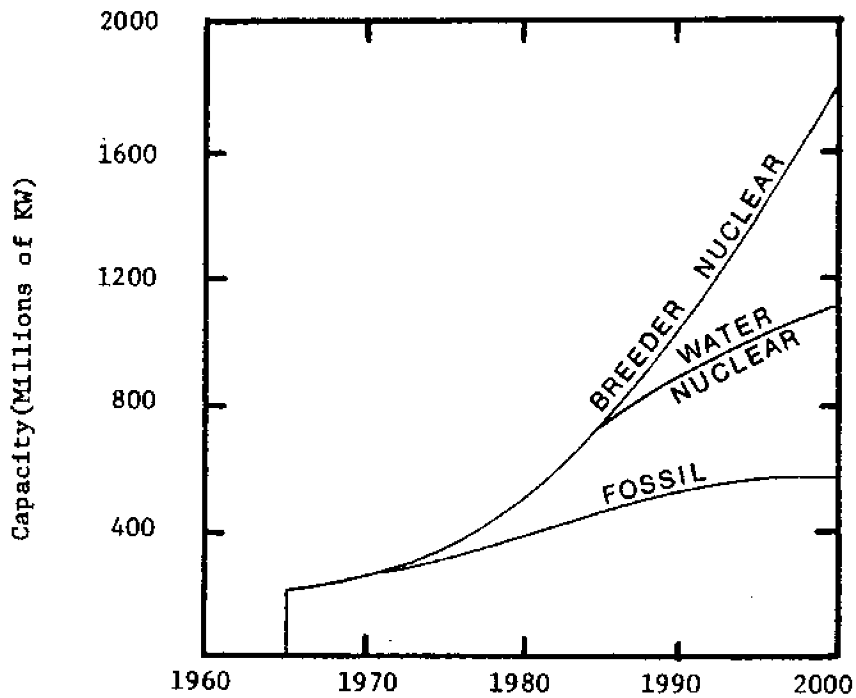
achieve an increase in the dissolved oxygen level - Table 8).

New land created by solid waste fill in estuaries is valuable as a source of new municipal taxable land for housing and industrial uses. But the value of land gained by filling is perhaps outweighted by the value of important marsh and intertidal land lost.

Nuclear power plants currently provide 5 percent of the nation's power output and this fraction is expected to increase steadily in the future.[20] Figure 1 shows the projected generating capacity of fossil, breeder, and water nuclear power plants to the year 2000. Assuming these water users should grow in numbers and become more widely distributed throughout the estuarine zone, their heat rejection capacity (projection in Figure 2) will grow steadily to the year 2000. This places a heavy burden on estuarine waters and increases their value as waste heat dissipators.

Desalination processes are currently uncompetitive with terrestial water sources. However, technological breakthroughs in the future will make desalination an attractive alternative for water supply and will put an increased value on unpolluted estuarine waters.

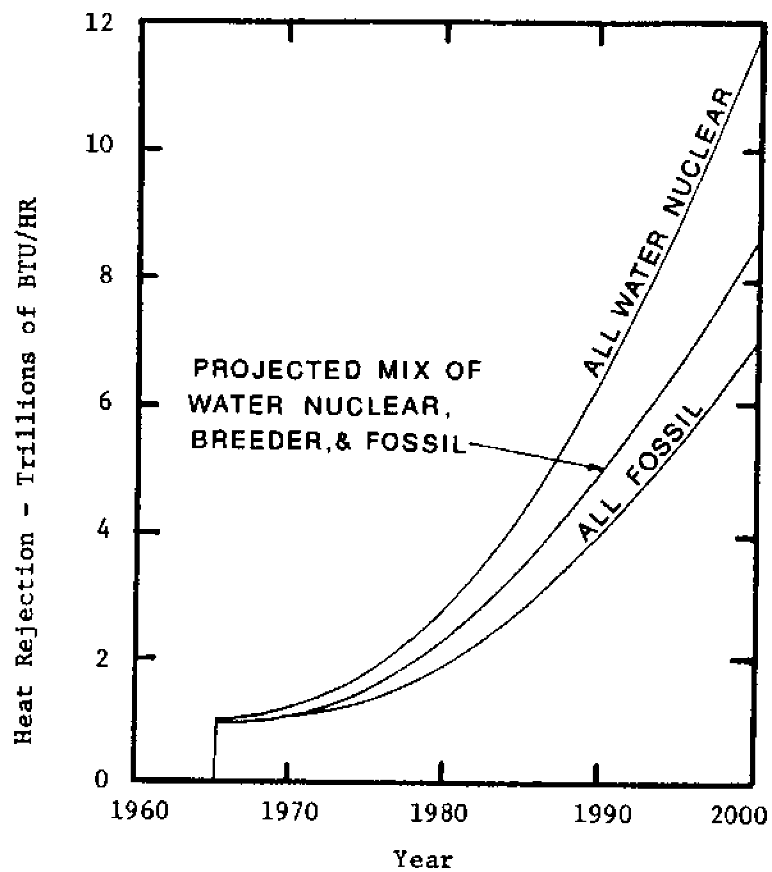
FIGURE 1: PROJECTED THERMAL GENERATING CAPACITY IN THE U.S.



Reference No. 20 Page 35, Appendix F

Source: United States Senate Ninetieth Congress, Second Session: "Thermal Pollution--1968 (Part I) Hearings before the Subcommittee on Air and Water Pollution of the Committee on Public Works", U.S. Senate, Washington, D.C. 1968

FIGURE 2: PROJECTED HEAT REJECTION FROM THERMAL GENERATING PLANTS



Reference No. 20 Page 77, Appendix F

Source: U.S. Senate: "Thermal Pollution Hearings", 1968

2.6 Extractive Industries

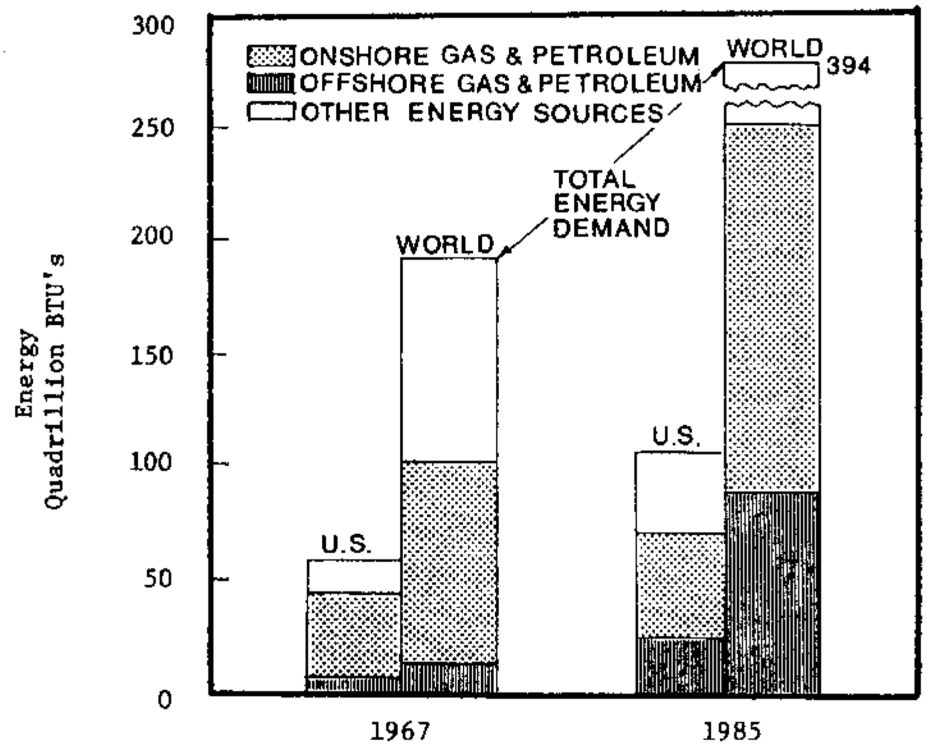
Extractive mining in and around the estuarine zone can be divided into three categories: petroleum, solution, and bottom mining.[20]

Offshore petroleum exploration technology will allow companies to move into deeper waters in connection with expanding operations. As exploration and production operations are extended into offshore coastal waters the estuarine zone will be affected because production, distribution and support facilities will remain tied to the estuaries. Figure 3 shows the projected increase in demand for offshore gas and petroleum as part of the total national and world energy demand.

Solution mining is the extraction of chemicals such as salt, magnesium, and bromine directly from sea water. Solution mining may be extended to the recovery of critical elements if methods can be found to avoid 100 percent processing of sea water to obtain small amounts of chemicals. Table 10 shows the annual values from sea water sources of these extracted chemicals and their percent U.S. value of the total world value. The competitive situation in solution mining would seem to limit the numbers of new production facilities to a few locations within coastal estuary zones.

Bottom-mined materials in the estuarine zone consist mainly of sand and gravel, oyster shells and sulfur, up to now. Figure 4 shows the categories of minerals that could be obtained if the technology for extracting them were at hand. Currently though, sand and gravel mining in close proximity to urban consuming centers and in connection with marina dredging and beach sand replenishment is the major bottom mining extractive industry.

FIGURE 3: PROJECTED DEMAND FOR OFFSHORE GAS AND PETROLEUM



Reference No. 20 Page 23, Appendix F

Source: "President of the United States: Marine Science Affairs - A Year of Broadened Participation", The Third Report of the President to the Congress on Marine Resources and Engineering Development, Washington, D.C. (January, 1969)

TABLE 10: U.S. PRODUCTION OF CHEMICALS THAT CAN BE OBTAINED FROM SEA WATER

Production[a] / Chemical	U.S. Annual (million tons)		Percent from Sea Water	Sea Water	
	Total	From Sea Water		Annual Value from Sea Water Sources ($ million)	Percent U.S. Value of Total World Value
Salt	35.0	1.4[b]	4	8	5
Magnesium Metal	0.09	0.081[c]	90	57	76
Desalinated Water	60.6	22.9	38	8	16
Bromine	0.14	0.068[e]	50	30	67
Magnesium Compounds[d]	1.37	0.47[e]	34	32	78
TOTAL				135	35

[a]Mostly 1966 figures.

[b]Includes solar sea salt and other solar salt.

[c]The only U.S. sea water magnesium facility is the Dow plant in Freeport, Texas (1965 figures).

[d]Includes magnesium chloride which, in turn, is used for magnesium metal.

[e]Includes sea salt-bittern.

REFERENCE: No. 20 Page 32, Appendix F

Source: "President of the United States: Marine Science Affairs - A Year of Broadened Participation", The Third Report of the President to the Congress on Marine Resources and Engineering Development, Washington, D.C. (January, 1969)

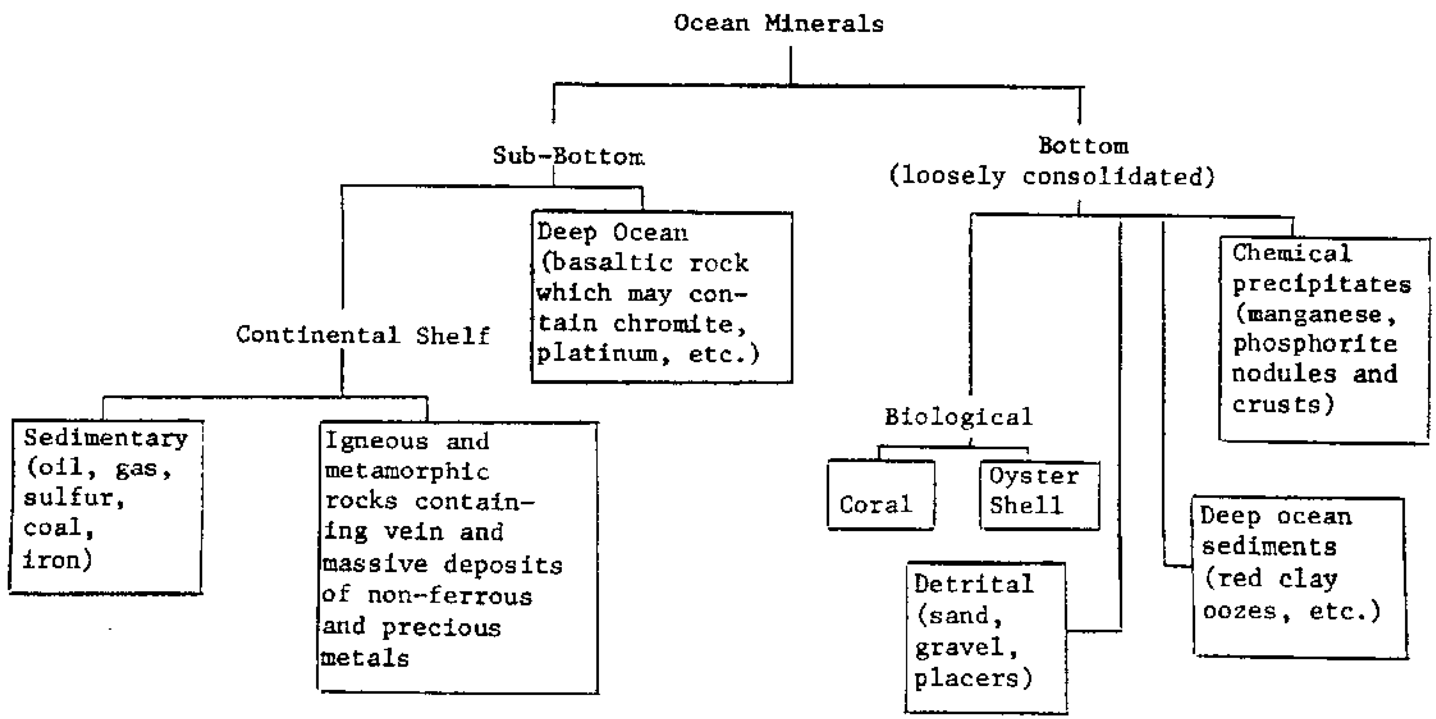


FIGURE 4: CATEGORIES OF OCEAN MINERALS

Reference No.20 Page 27, Appendix F

Source: Commission on Marine Science Engineering and Resources, "Industry and Technology: Panel Report, Vol. 2", U.S. Government Printing Office, Feb. 9, 1969

2.7 Flood Control

It has been found in recent decades that damage caused by coastal storms and hurricanes has drastically increased. Figure 5 shows statistics on the frequency of damaging coastal storms in the Eastern United States. The reasons for this increase in damage are:[19]

1. greater occupancy in the shore zone and its associated development mean that there is more damageable property in that zone;
2. unplanned development of coastal areas has weakened the natural coastal defences against storms and makes possible the increased dollar value of damage; and
3. better, more reliable, reporting of storm damage.

By their low lying nature, marshes and intertidal lands serve as natural barriers against hurricanes and storm floods. They do this by dissipating the energy of the storm surge with their vegetation cover and low gradient and by being the natural receptacles for surplus water of storm tides.

Figure 6 shows how fills are especially subject to the forces of a storm surge. They not only present sudden changes of slope to the storm surge but replace the area where the surplus water would have been stored. By reducing the space in which the storm water can be accommodated, the fill tends to raise the water level during storm tides. It can, therefore, be seen that the estuarine lowlands are economically valuable in protecting uplands from flood damage caused by storms and hurricanes.

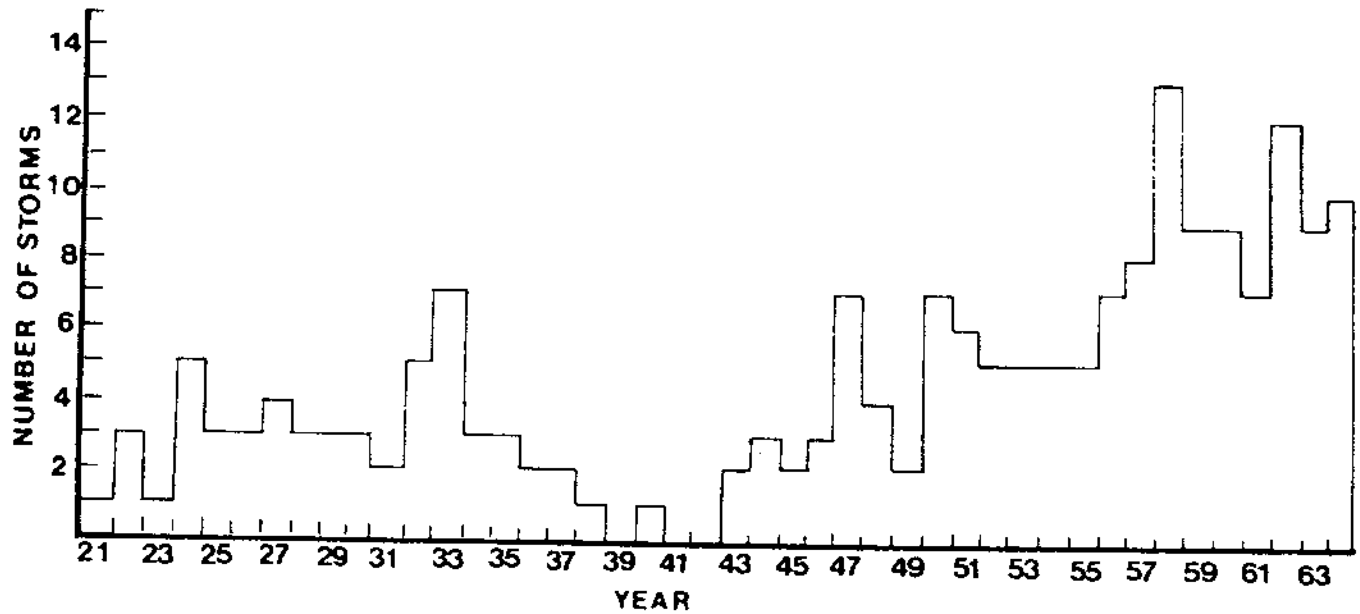
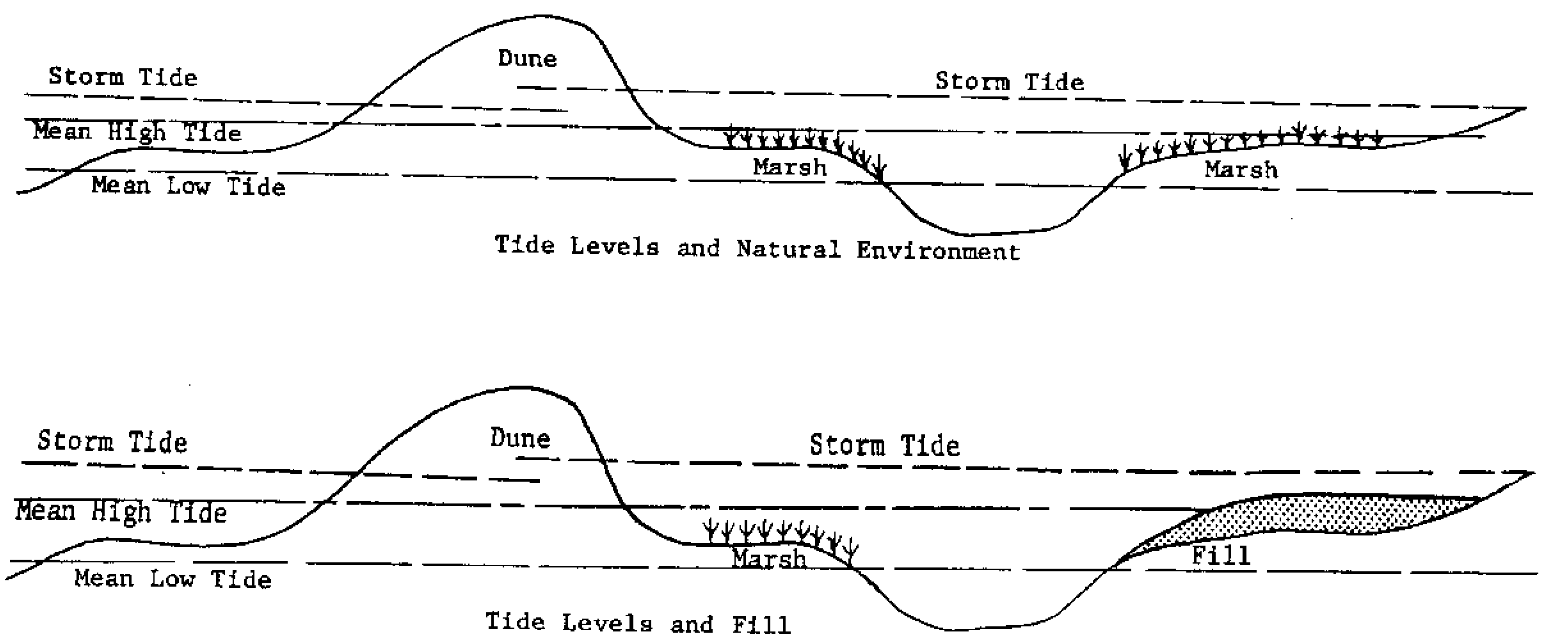


FIGURE 5: FREQUENCY OF DAMAGING COASTAL STORMS EASTERN UNITED STATES, 1921 - 1964

Reference No. 19 Page 3, Appendix C

Source: Burton, Kates, Mather, and Snead, Shores of the Megalopolis: Coastal Occupance and Human Adjustment to Flood Hazard. Publications in Climatology, Vol. XVII, No.3, Elmer, N.J. 1965

FIGURE 6: STORM TIDE EFFECTS ON NATURAL AND ARTIFICIALLY FILLED ENVIRONMENTS



Tide Levels and Natural Environment

Tide Levels and Fill

Reference No. 19 Page 16, Appendix C

CHAPTER 3

DESTRUCTION CAUSED BY MAN-MADE CHANGES IN THE ESTUARINE ENVIRONMENT

Changes are constantly being made in the estuarine environment. These changes range from large-scale construction such as ship channels to multitudes of small developments such as real estate encroachment. Agencies that bring about these progressive alterations may be grouped into four categories:[7] federal agencies and their sub-divisions, such as the Army Corps of Engineers, the Bureau of Reclamation, the Department of Agriculture, and the Bureau of Public Roads; private industry; state and municipal governments; and real estate developers. The justification for changes by these agencies or individuals depends upon the interests of the group bringing about these changes.

There are four principal activities which cause alterations of the natural balance in the estuarine ecosystem. They are: channel and stream flow diversion, industrial filling and encroachment, pollution of all sorts, and real estate developments.[7] The remainder of this chapter demonstrates how these activities cause destruction in the estuarine environment by limiting biological production of marine life.

3.1 Channel and Stream Flow Diversion

Upstream diversion of fresh water inflow into estuaries causes hydrographic changes in the area. In tide-dominated, vertically mixed estuaries, controlling the runoff with dam systems on rivers will change the steepness of the salinity gradient, possibly shortening the lengthwise freshwater-saltwater mixing zone. In estuaries dominated by high river flows (salt wedge type), the flow regime may be changed to the vertically mixed type by reducing or averaging out the surface runoff.[18]

When changes in the normal flow patterns in estuaries affect their circulation patterns, estuarine habitats are affected, usually to the detriment of organisms present. Even though these creatures are, by necessity, adaptable to changes in salinity with precipitation, storm surges, evaporation and runoff rates, a permanent change in estuarine conditions could only serve to drive these species out of their usual habitat.

For example, the Mississippi-Gulf Outlet Canal, a Corps of Engineers project connecting the city of New Orleans to Bretton Sound, has modified estuarine conditions in the marsh land east of the Mississippi River.[7] During flood periods the discharge of fresh water into the sound has been seen to limit oyster growth and production in the area. Conversely, the canal has caused salt water intrusion into the New Orleans area to such an extent that oyster production has developed in the pumping station of metropolitan

New Orleans.

In Texas, the Bureau of Land Reclamation planned to divert fresh water from all the rivers of eastern Texas flowing into the Gulf to irrigate the arid regions of western Texas.[7] This project threatened to completely cut off all fresh water inflow to the eastern Texas estuarine complex causing poisonous hypersaline conditions for fish and shellfish.[11]

Diversion of fresh water inflow can therefore cause destruction of biological production by altering the salinity in habitat areas, either limiting them due to circulation changes or destroying them with hypersaline waters.

3.2 Dredging and Filling

Dredging and filling in estuarine areas is, by far, the most destructive cause of physical alteration to estuary bottom and shore lands. In 1967, a survey by the Bureau of Sport Fisheries and Wildlife indicated that 7.7 million acres of the nation's 26.6 million acres of estuarine waters could be considered prime estuarine habitat for wildlife and aquatic species (see Table 11). Unfortunately, these are primarily the shallow areas and thus the most easily filled for development purposes. Approximately 7 percent of these important habitat wetlands have already been lost by dredging and filling in the past 20 years. About 45 percent of the basic habitat lost occurred in California's San Francisco, San Pablo, and Suisan Bays, where 243 square miles of wetlands had been filled by 1957.

Any occupation of tidal areas eliminates public use of the shore and access to the water, including enjoyment of the natural beauty of the shore and water landscape. But dredging and filling projects do multiple damage to estuarine productivity. A summary of these effects are:[18]

1. Filling eliminates the habitat and basic nutrient sources of the quiet tidal edges and marshes;
2. Dredging of submerged material deepens the water, decreasing the area of estuarine bottom that receives adequate light and is productive for basic plant life;

TABLE 11: FISH AND WILDLIFE HABITAT LOST IN PAST 20 YEARS

State	Acres of Estuaries Total Area	Basic Area of Important Habitat	Area of Basic Habitat Lost by Dredging and Filling	Percent Loss of Habitat
Alabama	530,000	132,800	2,000	1.5
Alaska	11,022,800	573,800	1,100	.2
California	552,100	381,900	255,800	67.0
Connecticut	31,600	20,300	2,100	10.3
Delaware	395,500	152,400	8,500	5.6
Florida	1,051,200	796,200	59,700	7.5
Georgia	170,800	125,000	800	.6
Louisiana	3,545,100	2,076,900	65,400	3.1
Maine	39,400	15,300	1,000	6.5
Maryland	1,406,100	376,300	1,000	.3
Massachusetts	207,000	31,000	2,000	6.5
Michigan[a]	151,700	151,700	3,500	2.3
Mississippi	251,200	76,300	1,700	2.2
New Hampshire	12,400	10,000	1,000	10.0
New Jersey	778,400	411,300	53,900	13.1
New York	376,600	132,500	19,800	15.0
New York[a]	48,900	48,900	600	1.2
North Carolina	2,206,600	793,700	8,000	1.0
Ohio[a]	37,200	37,200	100	.3
Oregon	57,600	20,200	700	3.5
Pennsylvania	5,000	5,000	100	2.0
Rhode Island	94,700	14,700	900	6.1
South Carolina	427,900	269,400	4,300	1.6
Texas	1,344,000	328,100	68,100	8.2
Virginia	1,670,000	428,100	2,400	.6
Washington	193,800	95,500	4,300	4.5
Wisconsin[a]	10,600	10,600	0	0
TOTAL	26,618,200	7,938,100	568,300	7.1
TOTAL[b]	26,369,800	7,689,700	564,100	7.3

[a] In the Great Lakes, only shoals (areas less than 6 feet depth) were considered as estuaries.

[b] Great Lakes shoals omitted.

REFERENCE: No. 6 Page 36

Source: U.S. Fish and Wildlife Service tabulation, p. 46, hearings on estuarine areas, House Merchant Marine and Fisheries subcommittee on fisheries and wildlife conservation, March 6, 8, 9, 1967.

3. Encroachment into the estuary basin reduces the intertidal volume (tidal prism) exchanged with each tidal cycle, reduces the amount of oxygen and nutrients brought in from the sea, and lowers the nutrient-trapping efficiency of the estuary; and
4. Reduction in the tidal prism also reduces the rate of flushing in the estuary thereby altering current strength, direction, and tidal phasing, possibly making parts of the estuary stagnant.

These changes all have related effects on erosion, shoaling, and mixing of nutrients, detritus, and oxygen in the estuary.

Furthermore, dredging activities cause troublesome sediment-suspension problems.[4] Sediment suspensions (turbidity) act to degrade water quality for recreation and other water contact uses. Turbidity inhibits production of aquatic plants by reducing the amount of sunlight they receive. Suspended sediment also creates adverse conditions for spawning of fish and setting of shellfish larvae. Sediment that settles out covers existing shellfish beds and limits the extent of new shellfish beds by cutting down the surfaces to which they may adhere.

If the area dredged is stagnant or impregnated with toxic wastes, its disturbance during dredging may release pollutants having lethal effects on estuarine life. Also, organic material placed into suspension would increase their oxidation rate and decrease the dissolved oxygen of the surrounding waters.[4]

In the past, the cost of hauling dredging spoils out to sea or to a suitable dumping ground demanded that the material be disposed of as close as possible to the non-productive marshlands. But as we discover more and more of the problems associated with dredge and fill practices in the estuarine zone we must be willing to amend these practices to preserve the estuarine habitat.

3.3 Pollution

Of all the uses of estuaries, waste disposal probably has the most potentially damaging results on the welfare of fish and wildlife. Disposal of solid wastes for fill in estuary basins causes trouble when chemical materials (acids, alkalis, detergents, tainting substances, etc.) leaching from this fill make the areas unsuitable for marine growth. Waterborne wastes cause similar problems when they are trapped in marshes and intertidal lands in much the same way that nutrients brought in with the tides and from upland river runoff are trapped.

Biocides, especially long-lived insecticides such as DDT, cause many ill effects on marine fish and wildlife. The following are some of these effects:[1]

1. Experiments indicate that DDT in very small concentrations can reduce growth and photosynthesis in certain marine plankton. Not only are these one-celled animals at the base of the food chain, but photosynthesis by marine plankton is estimated to account for more than half of the world's oxygen supply.
2. Marine organisms, especially crustaceans, are extremely sensitive to the persistent pesticides. As little as 0.6 to 6 parts per billion in water will kill or immobilize a shrimp population in two days. Shell formation in oysters was inhibited by concentrations of a few parts per billion.

3. DDT residues accumulated in the egg yolk of embryos poison the fry during final absorption of the yolk sac.

4. "Biological magnification" is a process that occurs when minute quantities of persistent pesticides are concentrated into more and more potent doses as they move up the food chain. This sort of magnification is thought to be responsible for the decline of many species of birds such as the bald eagle, osprey, peregrine falcon, and sparrow hawk.

Pollutants grouped according to their effects on the environment are tabulated on page 41. The sources of these pollutants are municipal and industrial plants such as petroleum, chemical, pulp and paper, tanning, rubber, coal, steel, canneries, meat processing, and waste heat from thermal power generation. These are called point sources and are currently being brought under federal controls. But decreasing pollution is difficult because the quality of estuarine water has been greatly degraded and costs of pollution control are high.

Non-point sources such as runoff from city streets, highways, animal feed lots, irrigated fields, urban lots, and waste fills are a more difficult problem. Control of this type of pollution must come through public education and wide-ranging abatement procedures.

TABLE 12: POLLUTANTS GROUPED ACCORDING TO THEIR EFFECTS ON THE ENVIRONMENT

1. nutrient salts in excess or in imbalanced ratios of nitrogen to phosphorus can cause buildup of heavy populations of undesirable algae imparting tastes and odors to water, displacing desirable phytoplankton and causing oxygen depletion upon death and decay.

2. organic wastes which have high oxygen demand such as sewage sludge, cannery and other food processing wastes, wood sugars from paper and pulp plants, and others.

3. toxic minerals and compounds such as heavy metals, acids, alkalis, etc.

4. toxic organic chemicals including biocides, detergents, cyanide, etc.

5. tainting substances: algae, some oils and petroleum wastes, phenols, some paper, rubber, and explosives' wastes, turpentine, resins, resin acids, etc., taint the flesh of food fish.

6. settleable and floating substances that suffocate bottom organisms, adhere to intertidal bottoms or to living animals and plants, including silts, clays, finely ground rock and other minerals, dusts, pulp, fibers, oils, greases, and tars, plastic fibers, etc.

7. radioactive wastes which may have genetic as well as lethal effects.

8. heat waste which may alter the ecology of water habitats for better or worse.

REFERENCE: No. 18, Page 131

3.4 Urban Development

Residential development is the dominant land use of coastal areas including many estuarine environments.[20] (See Tables 13 and 14 for breakdown of filled wetlands usage on Long Island and the Maine-to-Delaware coastline). Many urban centers are located on large estuaries (see Chap. 4). There are 40 million people living in ten metropolitan coastal areas having a population of one million or more. There are another 8 metropolitan areas of over one-half million people living within 30 miles (a 1-hour drive) of coastal estuarine shorelines.[20]

Sheer population numbers, coupled with the growth of estuary-oriented economic centers, will place heavy demands on estuary lands. Additional land will be needed for housing, industry, commerce, transportation terminals, and recreation facilities.

Urban growth will have four primary effects on estuaries:[20]

1. Competitive demands for existing waterfront lands will greatly increase. Shoreline is the most sought after location because the interface between land and water vastly increases the kinds of recreational activities available.
2. Developed urban land costs will accelerate proposals to create new manufactured lands within estuarine waters and wetlands.

To satisfy the demand for water-based housing, Delaware developers (and many others) have resorted to the construction of site development lagoons by dredging, filling, and bulkhead construction in estuarine wetlands. In their efforts to provide as many houses as possible with waterfront access they neglected environmental considerations. The lagoons not only destroyed the estuarine habitat they were built in, but they have turned into stagnant sewage traps which cannot be flushed by normal tidal action. (See Chapter 5 for further treatment of lagoon developments)

3. Waste disposal problems will become greater and will constitute an even more serious estuarine pollution problem.
4. Urban demands will multiply the number of space-demanding power, water and waste disposal facilities which accompany urban activity. Very often municipal officials find the appeal of newly developed and taxable lands for industry more attractive than undeveloped wetlands and marshes.

Water-oriented housing developments will continue to be a major factor for change in the estuarine zone but there are conflicts associated with this development.

TABLE 13: USES OF FILLED COASTAL WETLANDS IN LONG ISLAND: 1964

USE	ACRES	PERCENT
Housing	4357	34
Miscellaneous fill[a]	2505	20
Recreation	2094	17
Industry	1634	13
Marinas, docks, channels	732	6
Airports	479	4
Bridges, roads, parking	414	3
Waste disposal	177	1
Schools	108	1
Agriculture	96	1
Drainage	39	--
Total filled coastal wetlands	12635	100
Total coastal wetlands (1954)	43215	

[a] This term was used when ultimate use of the filled area was unknown

REFERENCE: No. 6 , Page E5

Source: Supplementary Report June, 1965, on the Coastal Wetlands Inventory of Long Island, New York, U.S. Dept. of Interior, Bureau of Sport Fisheries and Wildlife, Region-V, Boston, Massachusetts, p. 9.

TABLE 14: USE OF FILLED WETLANDS, MAINE TO DELAWARE: 1955 to 1964

USES	PERCENT
Dredged spoil	34
Housing	27
Recreation	15
Transportation	10
Industrial	7
Dumps	6
Other	1
TOTAL ACREAGE	45,000

REFERENCE: No. 6 , Page E7

Source: Clark, John, <u>Fish and Man: Conflict in the Atlantic Estuary</u>, Special Publication No. 5 (American Littoral Society, Highlands, N.J.: 1967).

One of the reasons the nation's larger cities were concentrated about estuaries was because of the abundant fish and wildlife there. Yet this same concentration of people produces wastes in the form of sewage dumping and industrial wastes which have reduced the quality of the waters to a level where fish and wildlife are in danger of being destroyed.

The present-day popularity of homes on bays and estuaries is also a paradox of uses. The very same resources and natural beauty that make these sites attractive are being destroyed by the developments themselves. This destruction is rarely necessary because alternative home sites usually are available on uplands near the estuarine shore which would preserve the intertidal lands and be safe from storm damage too.

Table 15 shows fifteen different uses of estuaries in the United States; the relative extent of their use now and in 1980; the dependence of that use on the estuarine shoreline; and the conflicts of the use with fish and wildlife, commercial fishing and recreation, all amenity uses of the estuarine zone. For urbanization this table shows that the extent of use of the estuarine zone is now moderate and it will increase by 1980. But its dependency (can the use reasonably exist elsewhere?) is small and its conflicts with the amenity uses are great. Therefore, urbanization is a bad alternative use of the estuarine zone. It would be better to leave the shoreline as is for amenity uses such as fish and wildlife nurseries, bird sanctuaries, and recreation facilities.

If a project's effect on the estuarine ecosystem is studied before construction, it is possible to limit the damage to biological production. In designing a marina for a tidal marsh, the decision of whether it should be built or not depends on the ability of the new design to limit destruction to biological production.

TABLE 15: USES OF ESTUARIES IN THE UNITED STATES—THEIR DEPENDENCY AND CONFLICTS

Use Categories	Extent		Dependency* 1/	Conflicts 1/		
	Now 1/	1980 2/		Fish and Wildlife VS	Commercial Fishing VS	Recreation VS
Agri. and Forestry	M	+	S	M	M	M
Commercial Fishing	G	+	G	S	-	S
Defense	M	+	M	M	M	M
Fish and Wildlife	G	+	G	-	S	S
Industry	M	+	S	G	G	G
Mining	M	+	M	G	G	M
Pest Control	M	+	M	G	M	M
Power Production	M	+	M	M	G	M
Recreation	G	+	G	S	S	-
Research and Educ.	S	+	G	S	S	S
Sanctuaries	S	+	G	S	S	S
Transportation	G	+	G	G	M	M
Urbanization	M	+	S	G	G	M
Waste Disposal	G	+	M	G	G	G
Water Supply	S	+	S	G	G	M

Legend

1/ S-Small
M-Moderate
G-Great
O-None

2/ (+) Increase
(o) Same
(-) Decrease

*Dependency is the degree of necessity for a use in, on, under, or immediately adjacent to an estuary. It asks: Can the use reasonably exist elsewhere or be accomplished in another way?

REFERENCE: No. 18, Page 151

CHAPTER 4

NEED FOR MARINAS IN TIDAL MARSHES

The preceding two chapters have shown the value of the estuarine zone, especially the intertidal lands, and the destruction caused by man-made alterations of these lands. It remains to be stated why there is a need for marinas in marshes.

Assuming that guidelines for building marinas in tidal marshes with the minimum environmental impact can be found (see Chap. 5), two questions must now be answered: (1) is there a future demand for marine recreation facilities, especially marinas; and (2) assuming the answer to the first question is affirmative, what is the need to build marinas in the estuarine zone, especially marshlands?

4.1 Demand for Marine Recreation

The National Outdoor Recreation Resources Review Commission has compiled data to predict outdoor recreation demand. Gross factors used as indicators to forecast recreation patterns are:[16]

1. growth of total population;
2. concentration of population in urban or metropolitan areas;
3. changing population characteristics of total population (employment, disposable income, etc.);
4. growth in leisure time; and
5. increased mobility of total population.

It was concluded that, as the levels of these factors rose, the growth of outdoor recreation demand for specific activities or opportunities would accelerate faster than the net increase in total population. To prove that there is, indeed, a demand for outdoor recreation facilities, statistics on each factor will be presented.

●Growth of Total Population

Today there are six times as many Americans as there were 100 years ago, and more than twice as many as there were 50 years ago. This growth is expected to continue in the future, though likely at a slower rate. Figure 7 indicates the population trends and projections for the years 1940-2015. The growth is expected to continue at a rate of 1.3 percent annually, with the total population of the United States increasing from a little over 205 million people in 1970 to about 400 million in 2020 [16] (using projections of Bureau of Census series "C", or medium low, assumptions which are becoming the most widely used of the Census Bureau's current projections).

●Concentration of Population in Urban Areas

Historically the United States has experienced four major population migrations from East to West, from South to North, from rural to urban, and from inner city to suburbs. Population decreases have occurred almost uniformly in the period 1940 to 1960 in the predominantly agricultural counties of the Midwest, the South, the Southwest, and Appalachia. In contrast those counties in which metropolitan development has occurred generally show steady increases during those years. During the same period only a handful of the 274 coastal counties in the coastal zone experienced any population decline.[16]

The growth of population in urban areas and relative decline in rural areas has been a steady trend in America since the first census was taken. In 1965, 67 percent of the country's population lived in urban or metropolitan areas. Figure 8 demonstrates this trend for the years 1790 to 1960.

The overall recent population growth rate in the estuarine zone economic region has exceeded that of the nation as a whole. From 1930 to 1960, the population of the coastal counties increased 78 percent, compared to a national growth rate of 46 percent. Future

FIGURE 7: ESTIMATES AND PROJECTIONS OF THE POPULATION OF THE UNITED STATES, 1940 - 2015

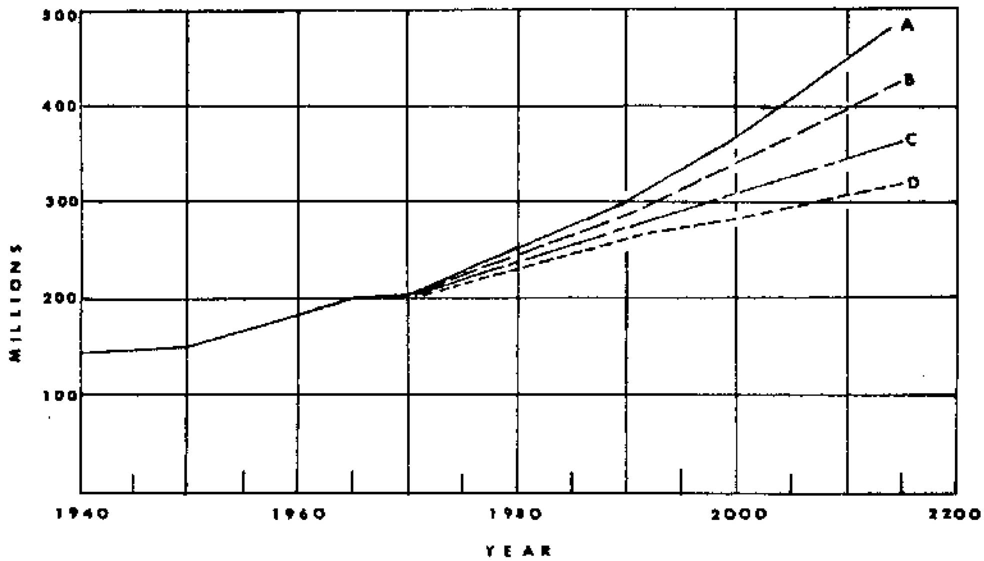
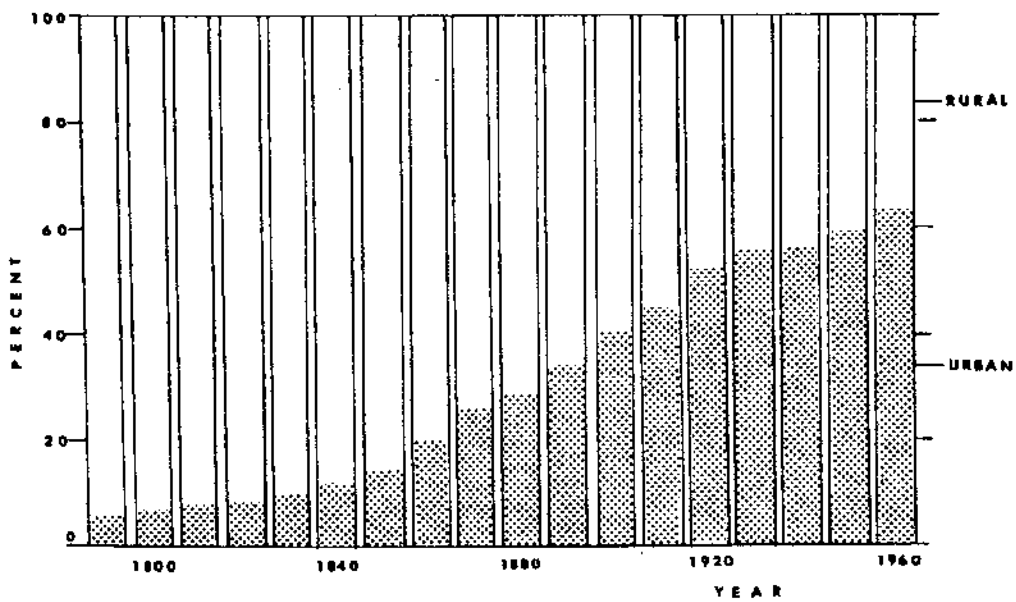


FIGURE 8: URBAN AND RURAL COMPONENTS OF TOTAL UNITED STATES POPULATION, 1790 - 1960



Reference No. 16 Pages 189, 191

Source: U.S. Bureau of the Census

population growth is projected to continue above the national average, but at a somewhat lower rate. Estuarine zone population is expected to more than double between 1960 and 2020 from 60 million to 139 million persons.[16] Approximately 35 percent of the nation's total population will then be located on the land area encompassed by the national estuarine economic region. Table 16 gives estimates and projections of population in the estuarine zone by economic region.

•Changing Population Characteristics

The amount of personal income generated in the economy indicates the general capacity to purchase goods, services, and amenities. Figure 9 shows a steadily rising trend and projection for U.S. personal income. Total personal income is expected to rise at a 5.1 percent annual rate of growth from 1970 to 2020. In terms of constant 1958 dollars, this represents an increase from about $615 billion to nearly $5 trillion in 2020. Similarly, per-worker earnings will increase substantially, rising from $6,000 in 1920 to $23,000 by 2020 as Figure 10 shows.[16]

The age composition of the population will also change in the future. Of particular significance is the expected rise in the main working age population (ages 25-64) from 86.4 million in 1966 to about 90.1 million in 1970 and 123.9 million in 1990.[16] Significant also is the shift of employment from the goods-producing industries such as agriculture, mining, and manufacturing to the service-producing industries of construction, government, trade and finance.

TABLE 16 - ESTIMATES AND PROJECTIONS OF POPULATION IN THE ESTUARINE ECONOMIC REGION AND INDIVIDUAL AREAS [In Thousands]

	1950	1960[1]	1970	1980	1990	2000
Estuarine economic region total population	45,302.1	57,946.2	68,396.9	76,606.7	92,940.0	106,900.3
Estuarine economic area population total:						
1. Maine coast	471.1	499.7	531.5	576.7	633.6	688.2
2. Massachusetts-R.I. coast	4,355.4	4,794.3	5,194.3	5,729.2	6,390.6	7,958.2
3. Connecticut coast	761.2	934.9	1,057.0	1,184.8	1,343.9	1,492.2
4. New York-northeast N.J.	13,593.6	15,603.5	17,376.5	19,114.4	21,061.0	23,022.3
5. Philadelphia-N.J.-Del.	4,399.3	5,320.8	5,939.9	6,661.5	7,567.1	8,505.8
6. Maryland-Virginia coast	4,473.0	5,739.5	6,812.8	8,023.3	9,573.3	11,172.1
7. North Carolina coast	447.1	511.7	529.0	546.1	582.7	623.0
8. South Carolina coast	374.8	466.2	503.2	539.0	595.7	662.2
9. Georgia-eastern Fla. coast	1,432.5	2,637.8	3,698.7	4,699.3	5,752.5	6,941.1
10. Southern Fla. gulf coast	547.7	1,058.7	1,369.0	1,663.1	1,931.0	2,302.7
11. Central Fla. gulf coast	98.0	126.5	134.2	150.2	171.0	198.1
12. Miss.- Ala.-west Fla. coast	563.0	818.5	977.0	1,135.3	1,363.3	1,603.2
13. Louisiana coast	1,177.8	1,535.3	1,814.7	1,974.4	2,168.6	2,930.0
14. Texas north gulf coast	1,324.7	1,900.8	1,206.7	2,710.4	3,304.1	4,026.1
15. Texas south gulf coast	441.5	563.8	635.6	704.1	792.3	878.2
16. Southern Calif. coast	5,233.5	8,224.9	10,826.2	13,586.9	16,906.1	20,381.0
17. Central Calif. coast	2,944.2	3,972.6	5,084.6	6,280.3	7,696.9	9,150.2
18. Northern Calif. coast	78.0	122.7	151.0	188.1	230.1	273.8
19. Oregon coast	1,091.4	1,276.8	1,389.3	1,602.7	1,849.6	2,087.7
20. Washington coast	1,493.7	1,837.3	2,165.5	2,536.8	2,972.6	3,444.1

[1]For purpose of uniformity, 1960 data is taken from April enumeration.

REFERENCE: No.16 Page 203

Source: Office of Business Economics, Regional Economics Division

FIGURE 9: ESTIMATED AND PROJECTED TOTAL PERSONAL INCOME IN THE UNITED STATES, 1950 - 2000

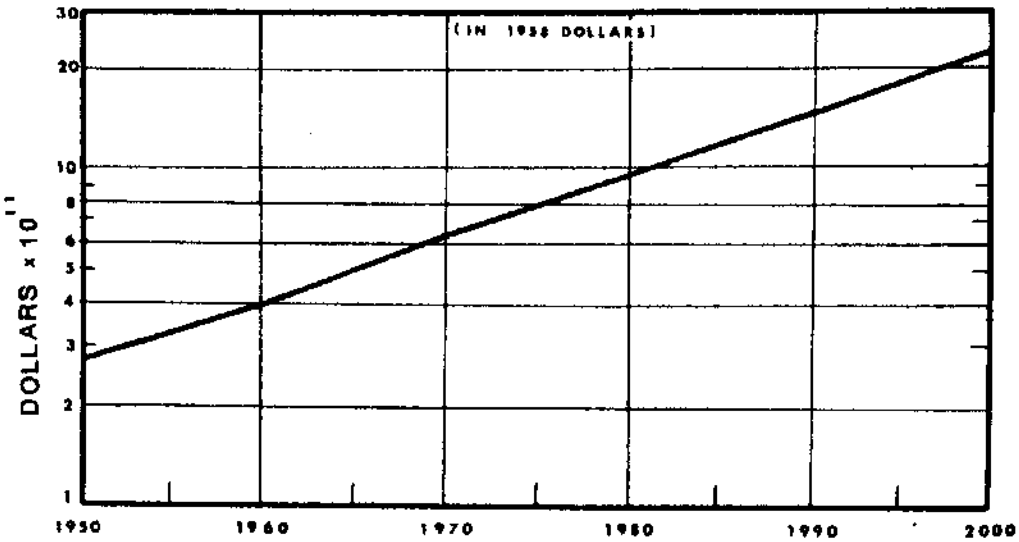
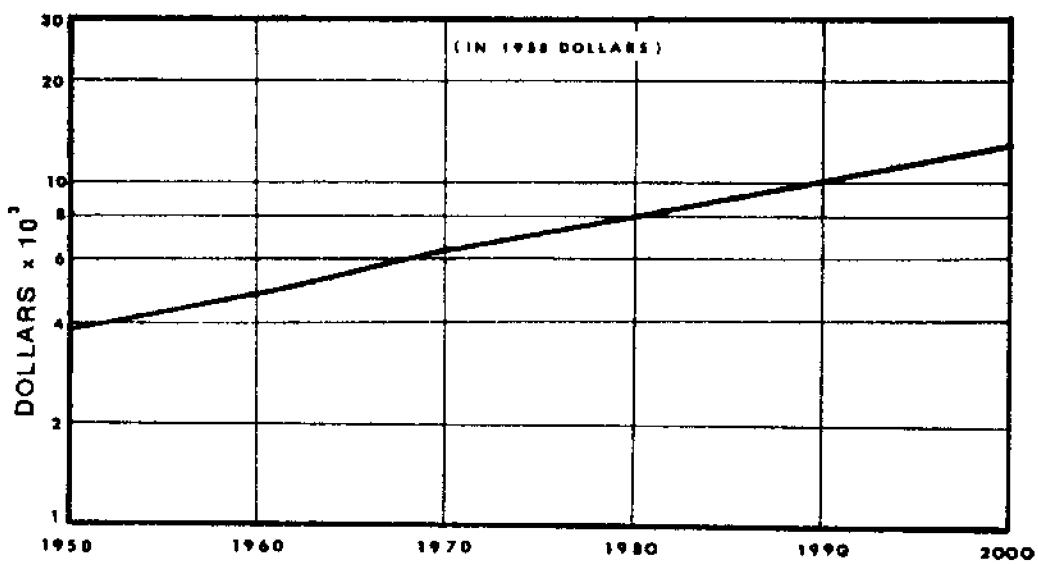


FIGURE 10: ESTIMATED AND PROJECTED PER-WORKER EARNINGS IN THE UNITED STATES, 1950 - 2000



Reference No. 16 Pages 192, 194

Source: U.S. Department of Commerce, Office of Business Economics, Regional Economics Division

•Growth in Leisure Time

Estimates of leisure time vary considerably, but all authorities agree that the workweek will shorten, from a conservative estimate of 35 hours a week to as little as 20 hours per week. The National Planning Association has projected that in 1990, 10 percent, and in 2020, 20 percent of the men between the ages of 25 and 54 will be granted a 1-year leave every 7 years.[16] Figure 11 illustrates the increase in leisure within the national time budget and the division of leisure for the years 1900, 1950, and 2000.

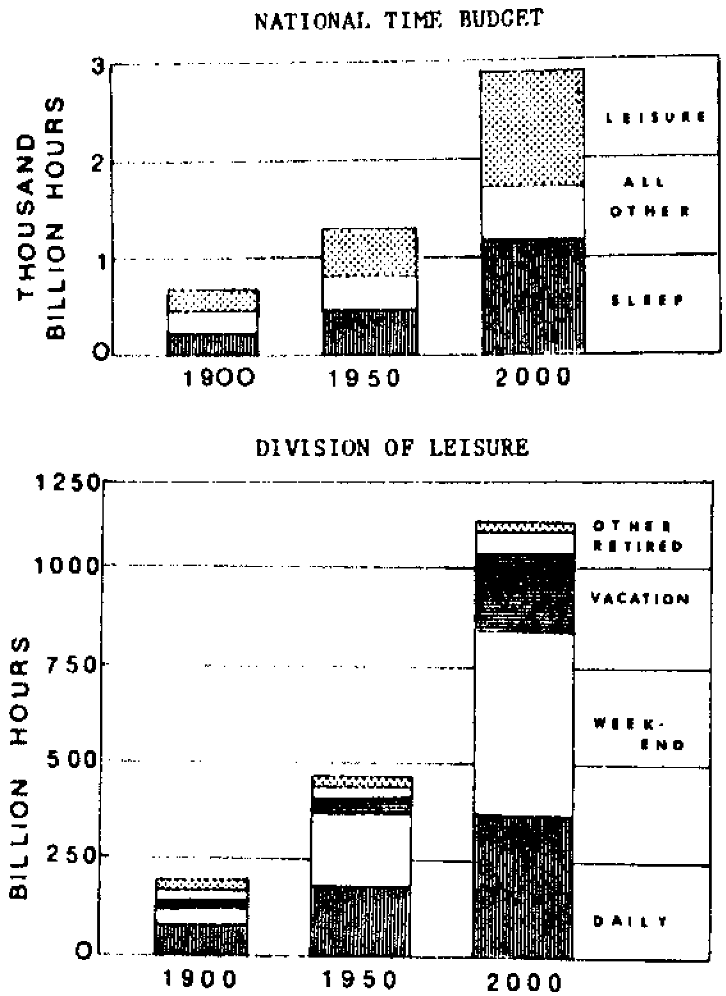
•Increased Mobility of Total Population

Mobility of the population depends basically on income and available time since transportation facilities are more than adequate to reach any recreation facility. With increased income and leisure time (already shown) the mobility is increased because of the ability to afford activities removed from place of residence.

Although no quantified data is available, the statistics on growth of each factor indicate a substantial rise in recreational demands in the future. The concentration of population in urban-estuarine zones and its predicted influx, further indicate that the greatest demands will be felt there. Figure 12 shows the predicted increase in demand for five selected outdoor recreation activities: water skiing, camping, boating, nature walks, and fishing.

An example of how these growth factors affect recreation demand, in particular boating, can be seen in a paper by

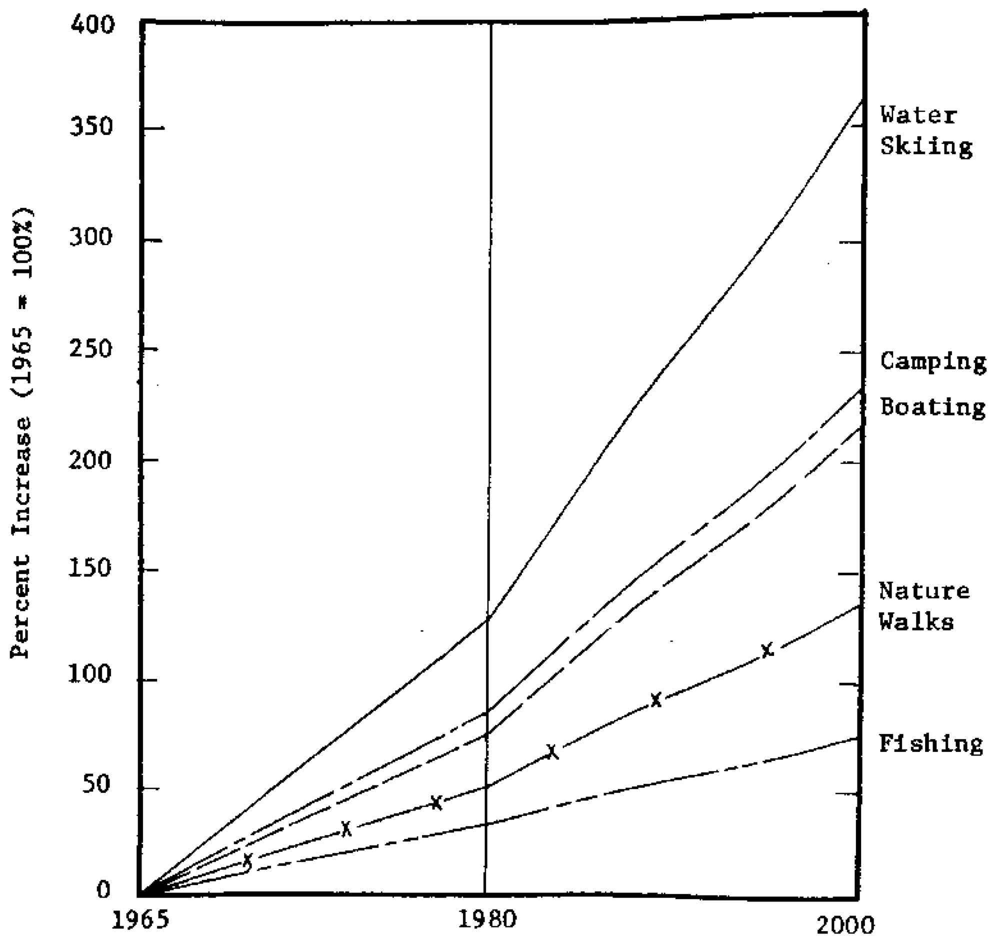
FIGURE 11: NATIONAL TIME BUDGET AND TIME DIVISION OF LEISURE, 1900, 1950, AND 2000



Reference No. 16 Page 232

Source: Marion Clawson, How Much Leisure: Now and in the Future, (Washington, D.C., Resources For The Future Inc., 1964)

FIGURE 12: PERCENT INCREASES IN SELECTED OUTDOOR RECREATION AREAS



Reference No. 16 Page 230

Source: Bureau of Outdoor Recreation

E. J. Gullidge titled Planning for Pleasure Boating on Regional Basis.[8] Therein are reported facts on a specific region.

In this, the Puget Sound area, the Seattle-Tacoma-Everett metropolitan complex has had a large labor influx resulting from industrial expansion. This coupled with an increasing per capita real income has produced a tremendous growth in pleasure boating activity in recent years (94 boats per 1,000 population compared to 40.8 nationwide in 1966). In order to project national outdoor recreation demands (exhibited by growth factors) to specific numbers for boating demands, the Seattle District Corps of Engineers conducted a pleasure boating survey to determine existing needs for moorages and launching ramps, as well as other marine facilities used by boaters.

A careful examination of present and future needs for marinas and small boat harbors is required to establish the impact on the environment, protect investments and properly allocate marine resources. Planning on a regional basis in a comprehensive manner allows a systematic approach toward the measurement of boating demand, both in terms of quality and quantity, thus providing confidence for those seeking to plan and develop facilities for this form of outdoor recreation.[8]

The strategy of the pleasure boating study consisted of the following elements: (1) inventory of existing facilities and shoreline to determine capacity for potential and further development; (2) measurement of marine facility demand by questionnaire survey of registered boaters residing within the study area; (3) comparison of demand with existing facilities to determine needs for additional facilities; and (4) projection of needs to 1980, 2000, and 2020.

The following assumptions were used in making projections of future moorage and launching ramp needs of pleasure boating: (1) the total growth in number of boats is directly related to population growth rates and increased per capita income in the study area; and (2) the demand for moorage and demand for boat launching ramps would grow at the same rate as pleasure boat ownership in the study area. The study projected a total pleasure boat average annual growth rate of 3 percent between 1965 and 1985 or 7/8 percent over the annual population growth rate projections for that area.[8]

In this same manner any regional authority can predict its pleasure boating demands based upon known population and disposable income growth rates. Because of growth factor trends in the estuarine zone already presented, it can safely be assumed that there will be a large demand for pleasure boating in the estuarine zone, and a demand for boating means a demand for marinas and other support facilities.

The method employed gives reliable estimates of current needs and reasonable projections of future ones. However, since pleasure boating is only one recreational activity whose demand is a function of many complex variables, a projection of long-range needs can only be viewed as an estimate.

Factors which may affect the demand of pleasure boating activity are:

1. The accuracy of population growth forecasts determines the accuracy of projected needs. Birth and fertility rates in the United States dropped to their lowest points in history last year and if the current trend continues, the U. S. would reach the stage of zero population growth sometime in the first half of the 21st century. Experts in population statistics emphasize, however, that trends in birth rates are ordinarily volatile.[12]
2. Overcrowding will limit the demand for recreational boating even if the population increases. It has been determined that boating is dependent upon open water space available and as open space decreases so will boating demand.[8]
3. Boating demand is difficult to separate from demand for boating-associated activities such as water skiing, fishing, skin and scuba diving. In general, an increase in these activities will stimulate an increase in boating demand.[6]
4. Latent demand (unfulfilled desire to participate) cannot be measured by a survey of the type used by the Seattle Corps of Engineers. The lack of adequate and available facilities suppresses the true demand for a boating

experience as well as disenchanting would-be boaters. As a result the true demand for boating facilities is higher than indicated by projections.[8]

5. The importance of water quality to boating activity was predicted by P. Davidson et al. in The Social Value of Water Recreation Facilities Resulting from an Improvement in Water Quality.[3] Their findings indicated that recreational water activities were only dependent upon availability of facilities, but that the quality of the water (oxygen content, purity, absence of odors, etc.) must be high enough to permit such activities. Although water quality is not as important for boating as it is for the contact sports of skiing, diving and swimming, a decrease in demand for these activities will affect the demand for boating. A cost-benefit analysis estimates that improved water quality conditions would stimulate large increases in use. For the special case of the Delaware Estuary they predicted that boating participation in man-days would increase from 2.58 to 3.08 million in 1960, from 3.28 to 3.84 million in 1975, and from 4.25 to 4.92 million in 1990 with an improvement in water quality.

On a national basis boating is a booming business. Boat owners are estimated to spend about three billion dollars on all types of new and used boating equipment, fuel, and services every year.[6] (See Table 18 for data on boating equipment sales for 1966) Boating has been growing at an annual rate of more than five percent per year and is likely to become even more popular. (See Table 17 for the estimated size of the pleasurecraft fleet in the U. S.)

In a nationwide study of 417 marinas by the National Association of Engine and Boat Manufacturers, it was reported that the lack of slips and moorings was the largest single factor retarding the sale of new boats and motors.[6]

The need for additional marinas and boating facilities has been demonstrated but the problem of where to put them remains.

TABLE 17: ESTIMATED NUMBER OF PLEASURECRAFT & ATTENDANT ACCESSORIES, 1966

Pleasure boats	8,275,000
Outboard boats	4,843,000
Inboard boats	591,000
Sailboats	561,000
Houseboats	5,500
Pontoon boats	22,500
Canoes	265,000
Inboard/outdrive	112,000
Miscellaneous craft	2,280,000
Outboard motors	6,904,000
Inboard engines	671,500
Inboard/outdrive units	125,000
Boat trailers	3,560,000

TABLE 18: BOATING EQUIPMENT SALES FOR 1966

ITEM	UNIT
Outboard boats	260,000
Inboard boats	36,000
Sailboats	13,000
Boat trailers	160,000
Outboard motors	444,000
Inboard engines	92,000
Inboard/outdrives	46,000
Waterskiis	810,000
Marine electronics gear ($)	17,500,000
Safety ($)	10,000,000
Fuel (gallons)	1,000,100

REFERENCE: No.6 Pages A26,27

Source: The Boating Business - 1967, The Boating Industry

4.2 Need for Marinas in Tidal Marshes

There are four basic reasons why there will be a need to build marinas in marshes in the future:

1. It has previously been shown that the population in the estuarine zone will increase faster than the growth of the national population. Table 19 lists the 18 largest coastal metropolitan areas in the United States and the names of the estuaries adjacent to them. The population of these areas alone is about 50 million or one fourth of the total U.S. population.[6] With such a large percentage of our population centered around the estuaries it is obvious that the demand for marine recreation will be greatest there.
2. A 1962 survey by the Outdoor Recreation Resources Review Commission found that only 4 percent of the nation's shoreline suitable for recreational pursuits was actually accessible for public recreational use.[6] The remainder of the land was either privately owned or restricted for use as government facilities or wildlife sanctuaries. So it seems that the shoreline available for construction of public recreational facilities, such as marinas, is severely limited.
3. The ability of marinas to expand is limited by the physical space in existing harbors. Even though many marinas have constructed more efficient

configurations of floats and expanded dockage by dredging and filling, the demand of increased boating numbers requires new marina facilities.[20]

4. Land in the marsh is often the most desirable location for a marina, because it is typically protected from severe weather (or there would be no marsh in the first place) and because it is fairly easy to dredge and otherwise manipulate.[20]

It can therefore be seen that there is a demand for new marina locations in the estuarine zone but the available shoreline is limited. Of the few remaining locations, since marshes are desirable locations, it seems reasonable to build our marinas there if a suitable design can be achieved.

TABLE 19: MAJOR COASTAL METROPOLITAN AREAS

Metropolitan area	1967 Population, millions[(a)]	Estuaries
New York - New Jersey	14.8	Long Island Sound
		New York Bay
		Jamaica Bay
Los Angeles	6.0	San Pedro Bay
Philadelphia	4.3	Delaware River-Bay
Boston	2.6	Massachusetts Bay
San Francisco	2.6	San Francisco Bay
Washington	2.1	Potomac River Estuary
Baltimore	1.8	Chesapeake Bay
Houston	1.4	Galveston Bay
Seattle	1.1	Puget Sound
San Diego	1.0	Mission Bay
		San Diego Bay
New Orleans	0.9	Lake Ponchartraine
Miami	0.9	Biscayne Bay
Tampa	0.8	Tampa Bay
Norfolk	0.8	Chesapeake Bay
Providence	0.8	Narragansett Bay
Anaheim	0.7	San Pedro Bay
San Jose	0.6	San Francisco Bay
Jacksonville	0.5	St. Johns River

[(a)] Executive Office of the President, Bureau of the Budget, Standard Metropolitan Statistical Areas, 1967, Washington (1967).

REFERENCE: No. 6 Page A-13

CHAPTER 5

MARINAS IN MARSHES - PROBLEMS & SOLUTIONS

To achieve a design for a marina in a marsh with the least possible environmental impact, it must first be determined what problems are caused by construction and operation in the marshland. The information gathered in previous chapters will be used in this determination. The valuable functions served by estuaries, shown in Chapter 2, will indicate which elements should be preserved in a marina development; whereas activities causing alterations in the natural estuarine balance, shown in Chapter 3, will indicate which practices should be avoided in a marina development.

Of all the valuable resource uses of the estuarine zone, biological production suffers the most damage when there are any man-made changes in the marshes. The marshes and intertidal lands are in a delicate balance with the tides which remove organics and cycle nutrients in the estuary. A difference in elevation of only 0.2 feet can mean a major difference in the vegetation produced on these intertidal lands.[5] It is obvious, therefore, that any dredging and filling will affect organic production, very often destroying what was previously productive land. With this loss of production would come a decline in fish and shellfish catches which are dependent upon the marshes and intertidal lands for food and shelter.

The recreational function of the estuary would be satisfied by a new marina development, but it must be recognized that recreational facilities are an exclusive use of estuarine resources. Space-use limitations restrict commercial cargo terminals based in the same area as recreational facilities, and concurrent water resource users must limit their activities to those which maintain the water quality necessary for recreational uses. Because water quality affects the demand for and the participation in recreational boating and its related water contact sports: skiing, diving, and fishing, point source users which dump effluent into the waters and the marina itself must maintain high water quality.

Storm flood damage caused by large urban encroachments into marshlands is not expected with a small boat marina development. A marina would require much less land for its development and the area within the marina would contain a substantial amount of open water (for berthing and turning basin) to receive storm flood waters.

Thus, the major impact of a marina on a tidal marsh would be in the areas of biological production and water quality control. If some way could be found to simulate the production of the marsh in a marina and maintain strict water quality control to insure that production, then a marina would be a viable usage for marsh development.

To illustrate the specific problems that occurred during marshland development, a brief account of the findings of a report to the Delaware State Division of Fish and Wildlife entitled "Environmental Impact of Dredge and Fill Operations in Tidal Wetlands Upon Fisheries Biology in Delaware"[2] would be most instructive. The study evaluated the condition of several former Delaware wetlands after dredge-fill operations had created lagoon-type real estate. The strategy employed in this investigation was to compare several natural embayments in the salt marsh with the dredged lagoons, determining biotic, water quality and circulation differences. In general, the lack of good water circulation brought about by low tidal amplitudes, reduced wind circulation, and reduced or absent fresh water inflow can have an adverse effect on an aquatic environment. Also, thermal and oxygen stratification can occur in lagoons or canals dredged below natural bay water depths and stagnant conditions may be established. In these unflushed lagoons accumulated plant nutrients may trigger an eutrophic condition if there is any nutrient-enriched runoff from uplands or sewer outfalls.

The report made recommendations for present and future lagoon developments which are also applicable to other developments in tidal marshlands, especially marinas. The remainder of this chapter is devoted to presenting these recommendations and more important, the proposed methods of implementation in marshland construction.

The report recommended that mixing and circulation be improved throughout the lagoon system. In the case of marina construction, this would mean providing a flushing mechanism to remove nutrients, increase dissolved oxygen, and inhibit stagnation.

A Florida firm has developed a patented system to solve this problem for dead-end lagoon developments in that state. The theory behind the system is that if a portion of the incoming tidal volume is forced to flow through the dead-end portion of the canal instead of back through the head, a one-way flowing river action would be created. The system is called a Tide-Pump* and it operates by placing a one-way valve at a site where a differential tidal level is obtained by having dissimilar length water arms or canals connecting to the main tidal body.

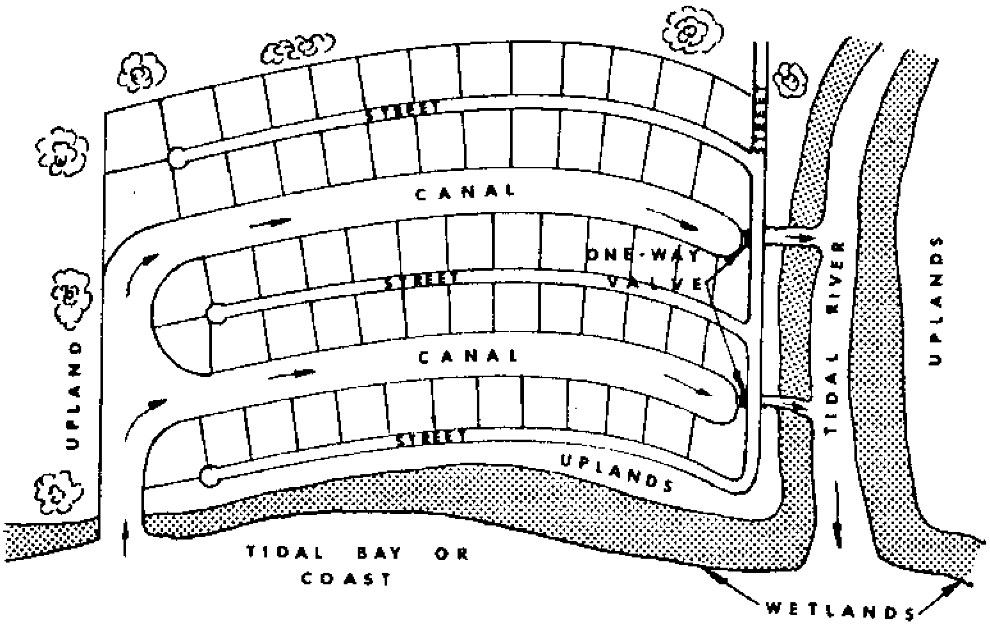
Figure 13 shows a plan for a flowing river canal system. The tide rises from right to left reaching the one-way valves on their discharge side first, closing them. As the tide continues to rise, the canals fill from the entrance channel upstream. After high water slack, the tide reverses and the level on the discharge side of the valves will be less than on the canal side, causing a one-way flow. This continues until low water slack when the valve closes as the tide begins to rise again.

In canals dredged deeper than surrounding natural bay depths the valve can have its suction pipe extended into deeper waters, removing stagnant bottom water and pulling clean water down

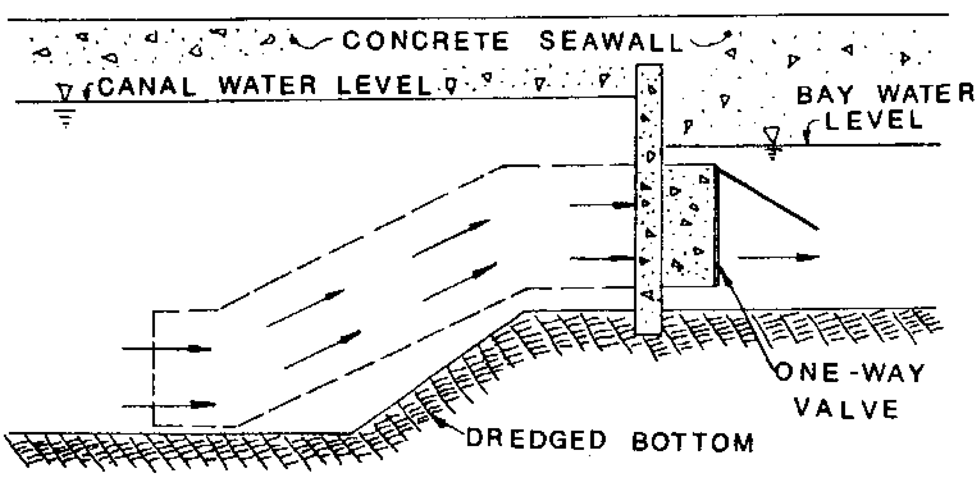
---

*This system is patented by: Environmental Canal Systems, Inc., Fort Myers, Florida.

FIGURE 13: TYPICAL "FLOWING RIVER" CANAL SYSTEM



ONE-WAY VALVE-CROSS SECTION



Reference: Environmental Canal Systems, Inc.

(see Figure 13). The problem is to engineer the lengths of the canal sections to develop enough head difference at the valve to provide the necessary flow volume to flush the system.

A system such as this would be adaptable to any marina configuration which provides two separate connections to a tidal body. The flushing action created is essential to a marina development with good water circulation free from waste and nutrient build-ups.

Another recommendation of the Delaware lagoon study was that dredge spoil should not be used for land fill. Chapter 3 has already shown the problems associated with dredge spoil disposal. It can't be placed on intertidal lands for fear of destroying finfish and shellfish habitats. Also turbidity associated with its disposal limits biological activity. The only alternative seems to be costly barging of the material out to sea to be dumped.

But it has been found [19] that land reclamation by diking of intertidal areas in Europe allowed deposition of fine silt, organic material and micro-organisms which serve as the basis for establishment of higher plant communities. In the situation of marina development, this would mean that it is possible to create artifical marsh communities using the dredge spoil already on hand. It would only be necessary to pick a non-productive shallow area and grade that area with the dredge spoil (already high in fines and organic content) in such a way that it becomes accessible over a wide area to intertidal waters. This would serve the dual purpose of maintaining biological production in the newly created marshland and acting to dispose of dredge spoil from the new marine recreation facility.

In locations where uplands (elevations above spring high tides) are adjacent to productive marshlands, there is the possibility of constructing the marina entirely in the upland area and providing access channels through the marsh. Utilizing the dredge spoil from these channels for new marshland, this type of development would cause the minimum environmental impact on the marsh, even benefiting it as a new marine recreation facility.

The lagoon study also recommended that dredged channels should not be bulkheaded but should have sloping banks, possibly stabilized by marsh grass. The disadvantages associated with vertical bulkhead walls are that they: limit contact surfaces for marine organisms to attach to thereby limiting biological production; create turbidity from boat wave effects on mud backfill used to support the vertical slab; and, vertical walls are highly reflective of wave energy, adding to general turbulence in the channel.

Dirt or grass sloping walls, suggested by the lagoon study, are not much better than the bulkhead design because they erode under boat traffic when binding vegetation is exposed at low tide. This erosion causes turbidity which adversely affects the marine life and the associated silting-up requires frequent maintenance dredging.

Solutions to the protection-siltation problem of channel bank stabilization have been proposed in the past. Figure 14 shows two such designs. The sloping concrete seawall (design A) provides protection for the channel banks, its sloping sides help to dissipate boat wake waves, and its "fishing reef" surface creates areas for marine organisms to grow and propagate.

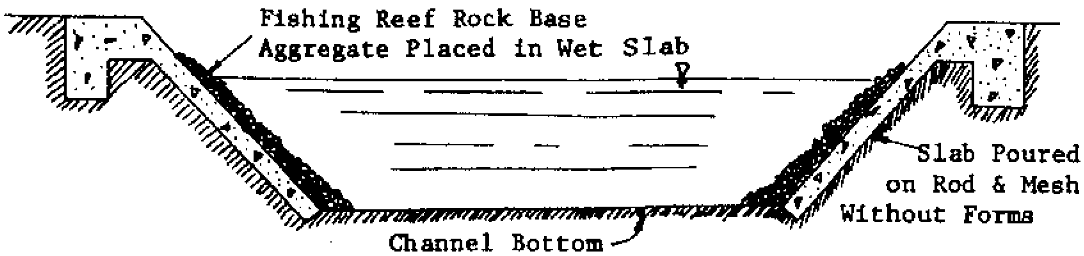
Design B represents standard rip-rap protection with an additional concrete base and toe to prevent settlement and shifting. This is a more expensive alternative but it has the advantages of dissipating wave energy and it provides much more surface area for marine organism growth. Either alternative will maintain water quality by reducing turbidity and help in biological production by providing a contact surface for organisms to attach to and shelter for their protection, in addition to their primary function of protecting the walls of the channels.

We have discussed the problems of flushing a marina, disposal of dredge spoils, and protection of channel sidewalls within the marina, Now we must turn our attention to the major problems of maintaining water quality and biological production within the marina itself. In order to maintain strict water quality control a method of waste collection and treatment must be devised for the marina.

A report to the Congress entitled Wastes from Watercraft[22] indicated that the threat to our navigable waters through pollution

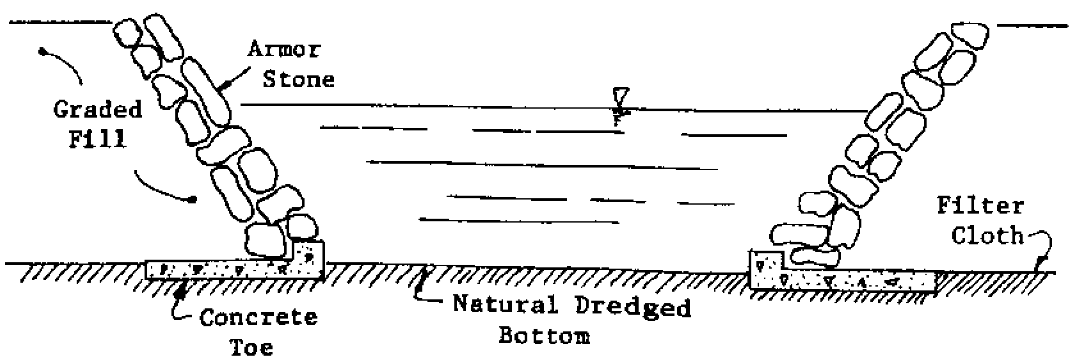
FIGURE 14: CHANNEL PROTECTION DESIGNS

A) The Sloping Concrete Seawall With Fishing Reef Rock Base



Reference: Environmental Canal Systems, Inc.

B) Rip-Rap Seawall With Concrete Base



from vessels of all descriptions is formidable, and needless. The basic charge of the Congress to investigate and report on vessel pollution in the navigable waters of the U.S. was contained in the Clean Water Restoration Act of 1966. A summary of the findings of this study with special attention to pollution from recreational watercraft follows:[22]

1. There are over 8 million recreational watercraft using the navigable waters of the U.S.
2. It is estimated that there are 1.3 million recreational watercraft which are toilet-equipped and discharge sewage into U.S. waters.
3. Recreational watercraft use tends to be concentrated on weekends, holidays, vacation periods, and during fair weather which coincides generally with water contact sport uses, thereby increasing health hazards and esthetic disturbances.
4. The trend in recreational watercraft is toward an increasing installation of onboard toilet facilities. This trend combines with an ever increasing number of recreational watercraft in use to indicate a steadily growing pollution problem from this source.
5. Sewage discharged from this source contains dangerous concentrations of pathogenic organisms that cause diseases such as dysentery, typhoid, gastroenteritis and infectious hepatitis. Also organic wastes foster

algal nuisances and accelerate eutrophication.

If a new marina is to be built, it will have to incorporate some type of pollution control system to meet expected federal and state water pollution control standards in the future. The most important part of this system will be the type of sewage equipment to be used aboard the watercraft. There are already four commercially available types of pollution control mechanisms for use aboard watercraft. They are:[22]

1. a holding tank which is a closed container for retaining sewage onboard until it can be properly emptied into an onshore sewage receiving facility. Properly designed and installed they are generally suitable for all types of watercraft, although their weight and size may make them difficult to install in existing larger craft .
2. incinerators, which burn up wastes, do not produce a noxious odor or excessive smoke when properly operated and leave only a small amount of ash residue. Incinerators may be used universally, but the fire hazard and power requirements when electrically fired make them less desirable on smaller watercraft and flammable cargo tankers.
3. macerator - disinfectors that grind up the solids, dose the mixture heavily with a disinfectant and

discharge an effluent directly into the water. Lack of reduction in BOD, organics, suspended solids and nutrients, questionable disinfection, and identifiable discharged solids make this use less attractive than others.

4. biological treatment facilities that remove the bulk of solid matter, followed by disinfection and discharge as acceptable effluent; this amounts to secondary biological treatment of sewage. The weight and size of biological treatment units limit their use to larger vessels only.

For use aboard small recreational pleasurecraft , holding tanks appear to be the only viable alternative. They completely prevent the discharge of sewage from a watercraft and their operation is subject to a minimum of mechanical or human failure. The long period of time during which this type of device has been in use makes it the most thoroughly tested system available. Their wide-spread use, however, is dependent on the installation in all ports of adequate shoreside receiving facilities which are generally not available at this time. But if a nationwide push toward watercraft pollution control is expected, designing these facilities into new marinas would be an economical and practical move which would at the very least control pollution in the vicinity of marinas for geological, esthetic and health purposes.

The remainder of the collection system in the marina depends upon: (1)the tidal range at the site; (2)the location of the marina with respect to existing sewer lines or a treatment facility; and (3) the amount of the collection system controlled by the marina operator and the boat owners.

To illustrate the alternatives involved, the findings of two studies on the collection and treatment of wastes from watercraft are presented. A study on houseboat wastes[17] for a community on a tidal river in Oregon appeared to be very comprehensive for various alternatives dealing specifically with a system for high tidal amplitudes. A study on pleasurecraft wastes,[21] prepared for the Federal Water Pollution Control Administration, dealt with one specific facility for handling wastes from watercraft in an area of low to moderate tidal amplitudes.

These alternatives are:

1. a gravity underwater system in which the onboard holding tanks are supplied with pumps. Each berth has a flexible connection to a collection system with gravity flow into an underwater storage tank. When the storage tank is filled, a separate pumping station empties it into tank trucks or barges for transportation to a distant sewage treatment facility. Or if a treatment facility is close at hand (on land or floating) the storage tank will serve to average

out peak weekend flows for treatment on a daily basis. For regions of high tidal amplitudes requiring larger pumps it is advisable to equip separate stations with these large pumps and flexible connections. This eliminates the need for pumps aboard each vessel and separate connections at each slip. Of course, the cost to the marina operator depends to a large extent on how much of the collection system is outside of the individual watercraft and this cost will have to be passed on to the users.

2. If the marina is situated close to an existing municipal sewage line or a connection can be installed at a minimum cost, the treatment and collection costs for the marina go down drastically. In areas of low tidal amplitudes, pumps onboard with flexible connections at each slip (or at central points) may be adequate to pump directly to the sewer line or treatment facility. In areas of high tidal amplitudes, a floating incremental lifting station must be provided to collect from the watercraft and pump (1 or 2 large head pumps) to the existing sewer line. In the high tidal amplitude case the marina operator is responsible for the bulk of the collection system (lifting station and

collection piping) whereas in the low tidal amplitude case the operator is only responsible for the piping, the pumps being maintained onboard the vessels.

There are many variations on the above alternatives depending on location, availability of existing sewer line nearby, space for on-site treatment facility, and pumping needs due to the tidal excursion. Either collection system, however, is expected to eliminate pollution and health hazards within the marina and maintain water quality suitable for biological and other waterborne, i.e., recreational activities.

If the biological productivity in a marina was any match for the activity in the displaced marsh, then the objective of minimizing ecological impact is partially achieved. By implementing the above recommendations, namely; (1) good circulation in the marina by flushing every tidal period, (2) strict sewage pollution control, and (3) channel protection with no turbidity but maximum contact area, an attractive alternative to preserve the community of marine organisms is possible. The problems remaining to be examined are 1) the impact on the supply of forage due to the removal of marsh grasses, and 2) the effects of boat traffic on the growth of biological species.

A report by Nixon et al.[13] of the University of Rhode Island, Ecology of Small Boat Marinas, looks into both of these problems. This study compared a small boat marina to a nearby tidal marsh for abundance of life present and relative pollution levels.

They found that marinas were not lifeless wastelands. In fact, many of the vital environmental life signs studied in marshes and marinas were found to be similar. The main difference in the two areas is that organisms known as fouling communities, which are not present in marshes, grow on submerged marina pilings and docks. Conversely, marsh grass is not found in great amounts in marina areas for lack of space. Where large pieces of organic matter from the emergent marsh appear to come in mid-winter and early spring and detritus is added throughout the year, the fouling communities have their maximum abundance in late summer. "Thus, in terms of delivery of food, the marshes and marinas may be compatible systems."

The fouling community may serve as an important food source for fish, especially the juveniles which attract sport fish. Diversity and abundance of fish species was found to be similar in both marsh and marina. Both area waters have enough dissolved oxygen for animal life to thrive. (This would be maintained by good water circulation). Suspended particulate matter on ebb tides from both areas was remarkably uniform throughout the summer. Nutrient samples analyzed did not indicate that either area showed abnormally high levels of phosphate or ammonia. Copper concentrations were low in both fish and phytoplankton but high in the fouling communities due to copper used in antifouling paint for boats and floats. The possibility of copper entering the food chain through the fouling communities suggests the use of antifouling paint should be discouraged, at least on marina floats. The environmental benefits should supersede the economic loss of decreased life span for unprotected floats.

The biomass of fouling communities included associations of barnacles, mussels, tunicates, sponges, amphipods, algae, and bacterial slimes. It was found that almost any free surface placed in coastal water will quickly develop an association of plant, animals, and bacteria living on it. Subtidal sections had a substantially larger biomass than the more stressed intertidal regions. They concluded that:[13]

> "While the maximum biomass of the fouling communities reached 5000 g/m^2, almost five times the standing crop of marsh grass, the organic content of the fouling communities averaged only 31 percent of its dry weight. The comparative value for Spartina grass is 89 percent. Thus a fouling community must develop about 3000 g/m^2 to equal the organic content of a 1000 g/m^2 marsh. This material however, is all available for consumption by fish, shrimp, etc., while only some 45 percent of the marsh production ever enters the water. In terms of food production available to the aquatic community,

only about 1500 g/m^2 of fouling must be developed to equal the input from a square meter of marsh (1000 grams)."

If the area in which a marina is going to be built is studied for its grass production ($grams/m^2$) and fouling community production (in g/m^2 on exposed test plates) an estimation can be obtained on the area of exposed surface needed in the marina to balance the marsh production displaced. With equivalent biological production the marina becomes a viable alternative for marsh development.

It should be emphasized here that although marshes should be preserved whenever possible, a small boat marina could be constructed in marsh areas to be compatible with the marsh environment.

So far this chapter has shown general concepts which, if implemented, would create a marina design with the least environmental impact on the surrounding marsh environment. The next chapter will use these guidelines and develop a composite marina design to serve as an example of a compatible marina-marsh system.

CHAPTER 6

COMPOSITE MARINA DESIGN

The general concepts outlined in Chapter 5 will now be brought together in a composite marina design. It must be recognized that it is the guidelines which are important to the design, not necessarily the methods of implementing them. There are any number of ways in which these guidelines may be incorporated into the marina design. The design presented here merely serves as an example of how they may be implemented. It is, by no means, a complete or unique marina design, but it stresses the factors which are important in minimizing the environmental impact.

From previous discussions in Chapter 5, the recommendations which should be implemented to maintain biological production and good water quality in a marina are:

1. the marina should be adequately flushed to promote water circulation;
2. spoil disposal should be fully utilized to create new marshland of comparable value to that which was dredged out;
3. channel sidewall protection should be provided which maximizes the area of contact for marine organism growth;

4. a collection system should be provided to remove wastes from watercraft and treat it if possible; and
5. the marina should maintain equal biological food production to that which was lost by displacing the marsh.

Before a design can begin a site must be selected. Assume for our purposes, a site is to be chosen in a broad marsh such as illustrated in figure 15. This region is classified as a broad marsh because it developed around the shores of a sheltered bay which provided protection such that the rate of marsh aggradation is equal to or greater than the rate of degradation.[5] The reason for choosing a broad marsh site rather than a fringing marsh or a back-barrier marsh is because broad marshes are usually the most prevalent type of marsh. The tidal creek and the ditches which drain into it provide access deep into the marsh so fish can feed at high tide and organics can be removed at low tide. The tidal range at the mouth of the creek is assumed to be 4 feet, 2 feet above and 2 feet below mean sea level. Spring tides fluctuate 3 feet about mean sea level. During storm conditions, when water is piled up onto the marsh, a 4-foot storm tide is assumed for this sheltered area. The marsh is protected by a low-lying barrier beach of sand and it extends from the beach to the 3 foot (above mean sea level) contour which delineates the upland from the marsh area. Soil borings in the area indicate that the marsh deposits are uniformly 6 feet in depth and overlay deposits of material suitable for fill in the construction of our

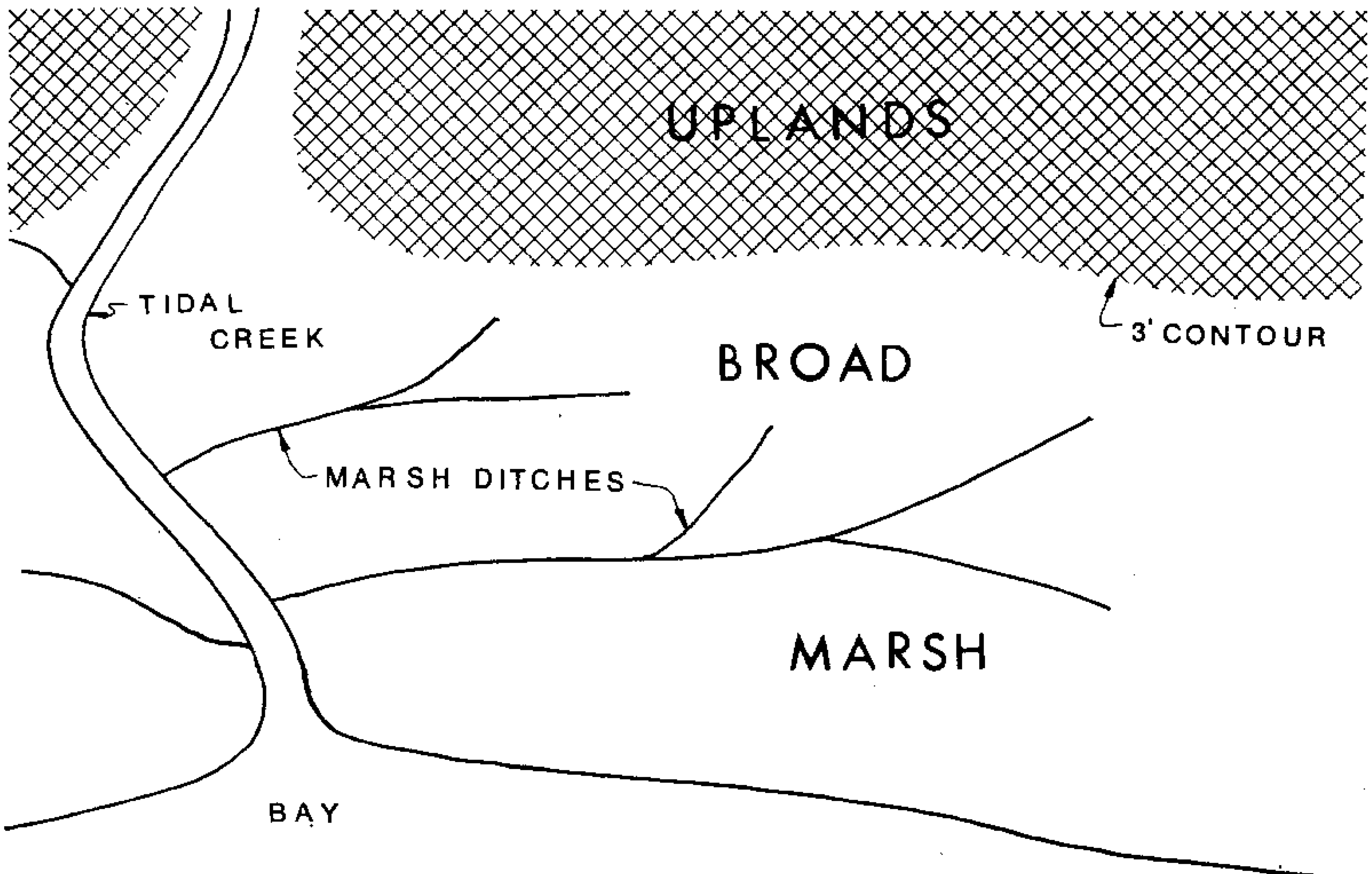


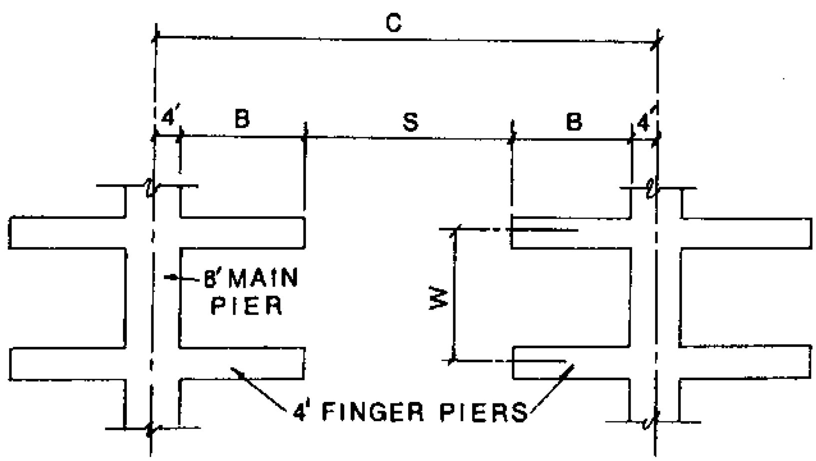
FIGURE 15: BROAD MARSH BEFORE MARINA DEVELOPMENT

marina. The location is such that a new road and power transmission line must be built to service the site. Also the site is far removed from existing sewage lines or, for that matter, from a sewage treatment plant. Experiments conducted at the site reveal that the organic production in the marsh is 1000 grams per square meter for marsh grasses. Also test plates introduced in the tidal creek and ditches revealed an average production from fouling communities of 1500 grams per square meter. In the immediate vicinity there is no suitable area where dredge spoil may be disposed of, but further down the bay a sheltered cove with an average depth of 10 feet below mean sea level could be used to create a new marshland.

The configuration of the marina will depend upon the number of boats it will serve, the layout of the facilities, and the criterion of providing a flushing mechanism. Assume the marina must serve 200 boats. To determine the berth requirements for these boats, a size distribution must be assumed. From data on typical distributions in small boat marinas[14] the assumed distribution in table 20a was chosen. By using this distribution, we can calculate the number of berths needed in the different size categories. Table 20b gives minimum dimensions for berths and slips for a typical berthing arrangement shown. Knowing the number of berths needed and their minimum dimensions a layout for the berthing arrangement may be developed. Figure 16 shows an example of such a layout.

TABLE 20a: BERTH REQUIREMENTS

Length of Berth, B in feet	Size Distribution % of Total (200) -Assumed-	Number Berths Needed
20 and under	35	70
20 to 30	45	90
30 to 40	15	30
40 and up	5	10



TYPICAL BERTHING ARRANGEMENT
(not to scale)

TABLE 20b: MINIMUM DIMENSIONS FOR BERTHS AND SLIPS

Length of Berth, B in feet	Width, W in feet	Slip, S in feet	Center to Center of Piers, C in feet
20	20	35	83
30	28	55	121
40	32	70	158
50	36	100	208

REFERENCE: No. 14 Pages 31 & 32

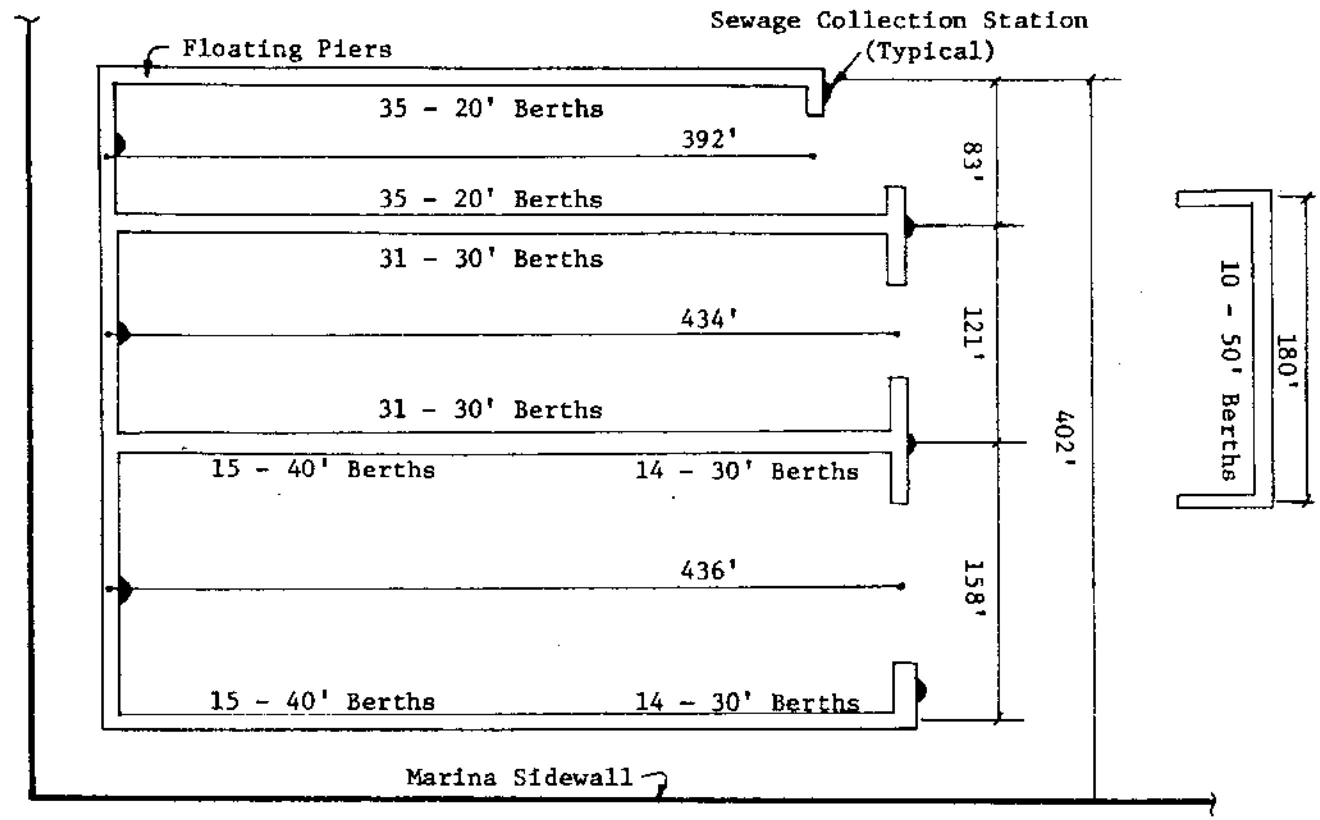


FIGURE 16: LAYOUT FOR BERTHS AND SLIPS

Figure 17 shows the master plan for the proposed marina. It is developed around the space requirements for berthing the boats. The facilities supplied are similar to those in any small boat harbor: launching ramp, covered boat storage, repair shop, parking, restaurant, etc. Note that the area taken up by parking, boat storage, and the repair shop (approximately 330,000 square feet) is on the upland portion of the site (by comparing with figure 15). The placement of parking, storage, and other support facilities on nearby uplands is consistent with our objective of minimizing environmental impact by reducing the area of productive marshland displaced by the marina.

To comply with the requirements for our composite design, the marina is flushed by the mechanism of a one-way flowing river system described in Chapter 5. The marina basin is connected by a channel to a surge basin which builds up water volume prior to flushing into the tidal creek when the one-way valve opens. To estimate the flushing potential of this system, assume that the 4-foot tide range produces a maximum differential head of 6 inches at the one-way valve during maximum ebb. (This assumption should be verified by computer or physical modeling of the system in any actual design.) Minimum basin depths in a small boat marina are:[14] 15 feet for main basin channels, 12 feet for access slips and, from 8 to 12 feet for berths depending upon boat length. For calculation purposes, assume a constant depth of 12 feet in the marina at mean low water. The surface areas of the basins are:

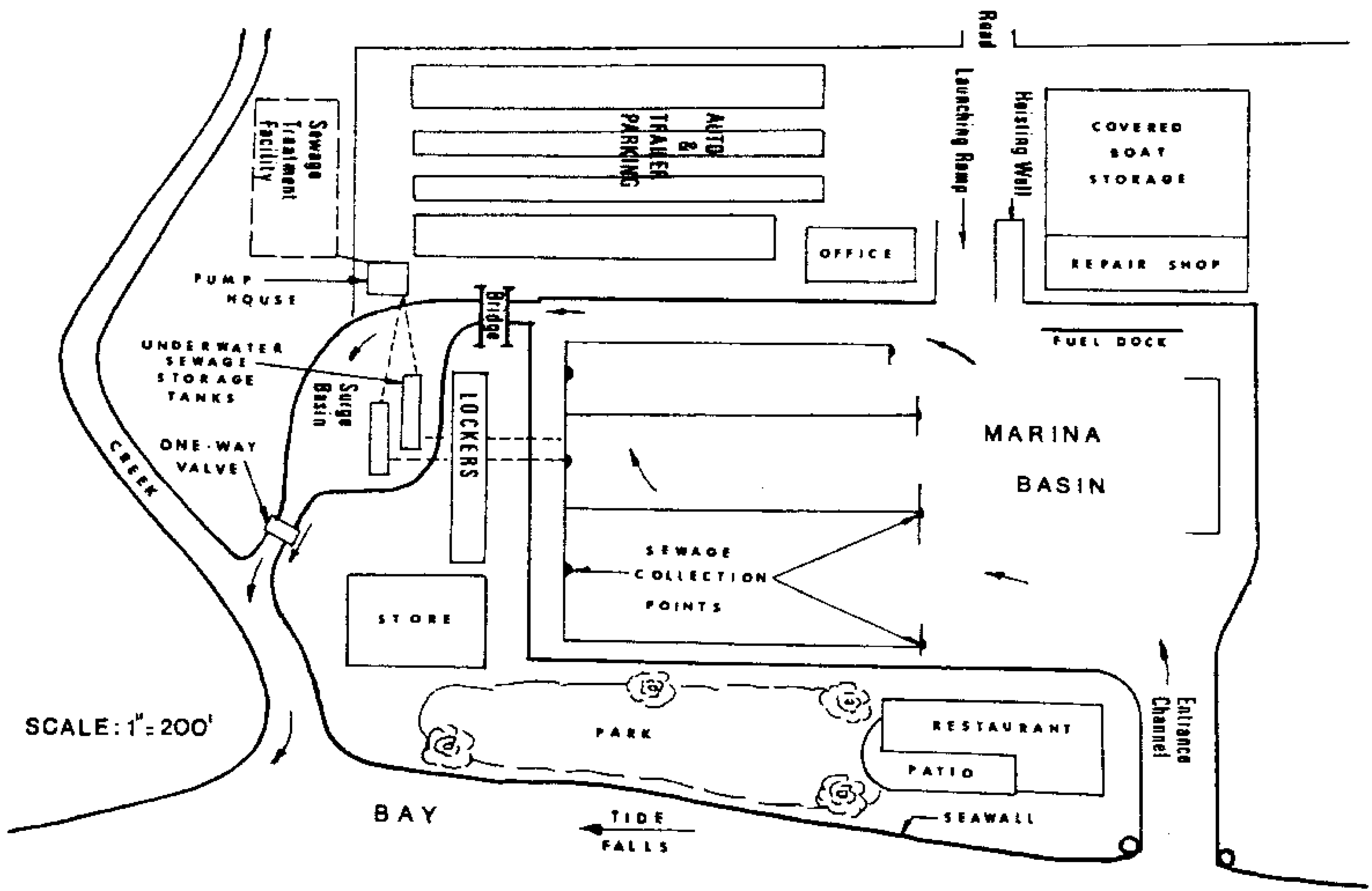


FIGURE 17: MARINA DEVELOPMENT IN FORMER MARSH

marina basin:	900' x 450'	$= 4.05 \times 10^5\ ft^2$
surge basin:	250' x 200'	$= +0.50 \times 10^5\ ft^2$
total surface area:		$= 4.55 \times 10^5\ ft^2$

The volume of the marina at:

mean low water	(depth = 12')	$= 5.46 \times 10^6\ ft^3$
mean sea level	(depth = 14')	$= 6.37 \times 10^6\ ft^3$
mean high water	(depth = 16')	$= 7.28 \times 10^6\ ft^3$

For a 6-foot diameter one-way valve the cross-sectional area is 28.27 ft^2. The velocity through this valve at maximum ebb is obtained from head loss considerations:

$$\text{HEAD LOSS} = \left(\begin{matrix}\text{Entrance Loss}\\ \text{Coefficient}\end{matrix} + \begin{matrix}\text{Exit Loss}\\ \text{Coefficient}\end{matrix}\right)\frac{v^2}{2g}$$

We must solve for v, the velocity through the valve for a head loss of 6 inches or 0.5 feet, entrance loss coefficient of 0.4, and exit loss coefficient of 1.0. We obtain:

$$v^2 = \frac{0.5(2)(g)}{(0.4 + 1.0)} = \frac{g}{1.4} = 23.0$$

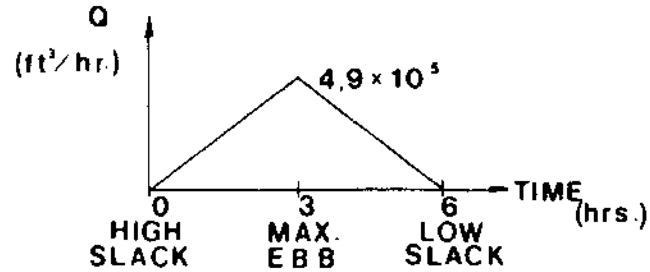
$$v = 4.8\ \text{ft/sec}$$

and the discharge is:

$$Q = vA = 4.8\ (28.27) = 135.7\ ft^3/sec$$

$$= 4.9 \times 10^5\ ft^3/hour$$

This is the discharge at maximum ebb. To determine the discharge over a full tidal cycle, assume a triangular flow variation with time. This would be a conservative assumption since the flow variation is more nearly sinusoidal. Remember that the valve only stays open over the six-hour period when the tide is ebbing and closes when flooding; we have:



The total flow through the valve is the area under the triangle or:

$$Q_{Tot.} = (0.5)\ (6)\ (4.9\text{x}10^5) = 1.47 \times 10^6\ \text{ft}^3/\text{Tidal Cycle}$$

At mean low water, assume there is a concentration, C_1 (Lbs/ft^3), of pollutants in the marina. When clean water enters during flood tide, this concentration is diluted to a level, C_2 (Lbs/ft^3), by the volume of water entering the marina (assuming full mixing of the water).

$$C_2 = (C_1)\ \frac{\text{Volume at MLW}}{\text{Volume at MHW}}$$

The original amount of pollutants in the marina is: $V(\text{M.L.W.}) \cdot C_1$

The amount of pollutants flushed out of the marina through the valve during one tidal cycle is:

$$(Q - \text{ft}^3/\text{Tidal Cycle})(1\ \text{Tidal Cycle})\ (C_2 - \text{Concentration at M.H.W.})$$
$$= V(\text{valve}) \cdot C_2$$

Therefore the amount of pollutants remaining in the marina are:

$$[V(\text{M.L.W.}) \cdot C_1] - [V(\text{valve}) \cdot C_2] = V(\text{M.L.W.})\ C_f$$

where C_f is the final concentration in the marina when flushing is completed and the water level has reached mean low water. Solving for C_f above:

$$C_f = C_1 - \frac{V(\text{valve})(C_1)}{V(\text{M.H.W.})} = C_1 \left(1 - \frac{V(\text{valve})}{V(\text{M.H.W.})}\right)$$

The fraction of pollutants remaining of the original amount is: $\frac{C_f}{C_1}$

The percentage of pollutants removed is:

$$\left(1 - \frac{C_f}{C_1}\right) \times 100 = 1 - \frac{C_1}{C_1}\left(1 - \frac{V(\text{valve})}{V(\text{M.H.W.})}\right) = \frac{V(\text{valve})}{V(\text{M.H.W.})}$$

$$= \frac{1.47 \times 10^6 \text{ ft}^3}{7.28 \times 10^6 \text{ ft}^3} \times 100 = 20.2\%$$

The efficiency of the one-way valve in removing pollutants from the marina is 20% for one tidal cycle. That is to say, 20% of the pollutants in the marina at mean low water are removed by the flushing mechanism before the next low water.

The total marsh surface area taken up by the marina development is 7.2×10^5 ft^2 (about 1200' x 600'). When the marina basin is dredged to 14 ft below mean sea level (former marsh surface), the top 6 ft of this material is marshy dredge spoil material and can be used to create new marshland in the cove area previously mentioned. The volume of this organically rich dredge spoil is 4.32×10^6 ft^2 (7.2×10^5 ft x 6 ft). If it is placed in the cove area and graded to mean sea level, 4.32×10^5 ft^2 of new marsh will be formed ($4.32 \times 10^6 \div 10'$). Model studies of the location of this new marshland would be helpful in determining its effect on overall estuarine circulation, erosion, and deposition. The model study may indicate that the fill cannot be used in that location, in which case it would have to be barged out to sea and we would have to rely on the biological production within the marina to make up for the marsh grass lost.

The biological production in the marina occurs in the fouling communities which attach themselves to the bottoms of marine floats, pilings, and in the interstices of the rubble which makes up the channel protection. Figure 16 gives the dimensions for the float layout in the marina. From this we can calculate the available area for marine organism growth, assuming only bottom areas:

Pier length x width x number

$$
\begin{array}{r}
436 \times 8 \times 2 \\
+\ 434 \times 8 \times 1 \\
+\ 392 \times 8 \times 1 \\
+\ 362 \times 8 \times 1 \\
+\ 180 \times 8 \times 1 \\
\hline
= \quad 17{,}920
\end{array}
$$

$\frac{\#\ \text{Berths}}{2}$ x Length x Width

$$
\begin{array}{r}
\frac{70}{2} \times 20 \times 4 \\
+\ \frac{90}{2} \times 30 \times 4 \\
+\ \frac{30}{2} \times 40 \times 4 \\
+\ \frac{10}{2} \times 50 \times 4 \\
\hline
= \quad 11{,}600
\end{array}
$$

or a total float surface area of 29.5×10^3 ft^2.

To calculate the additional surface area supplied by the channel protection structure, we must first choose a design for the structure. The rubble mound structure of Figure 14, Chapter 5, will be used for this design (see Figure 18). The height of this structure will be 20 feet to accomodate a storm tide superimposed on a spring high tide in the area. The slope will be 1/2 and a cast concrete

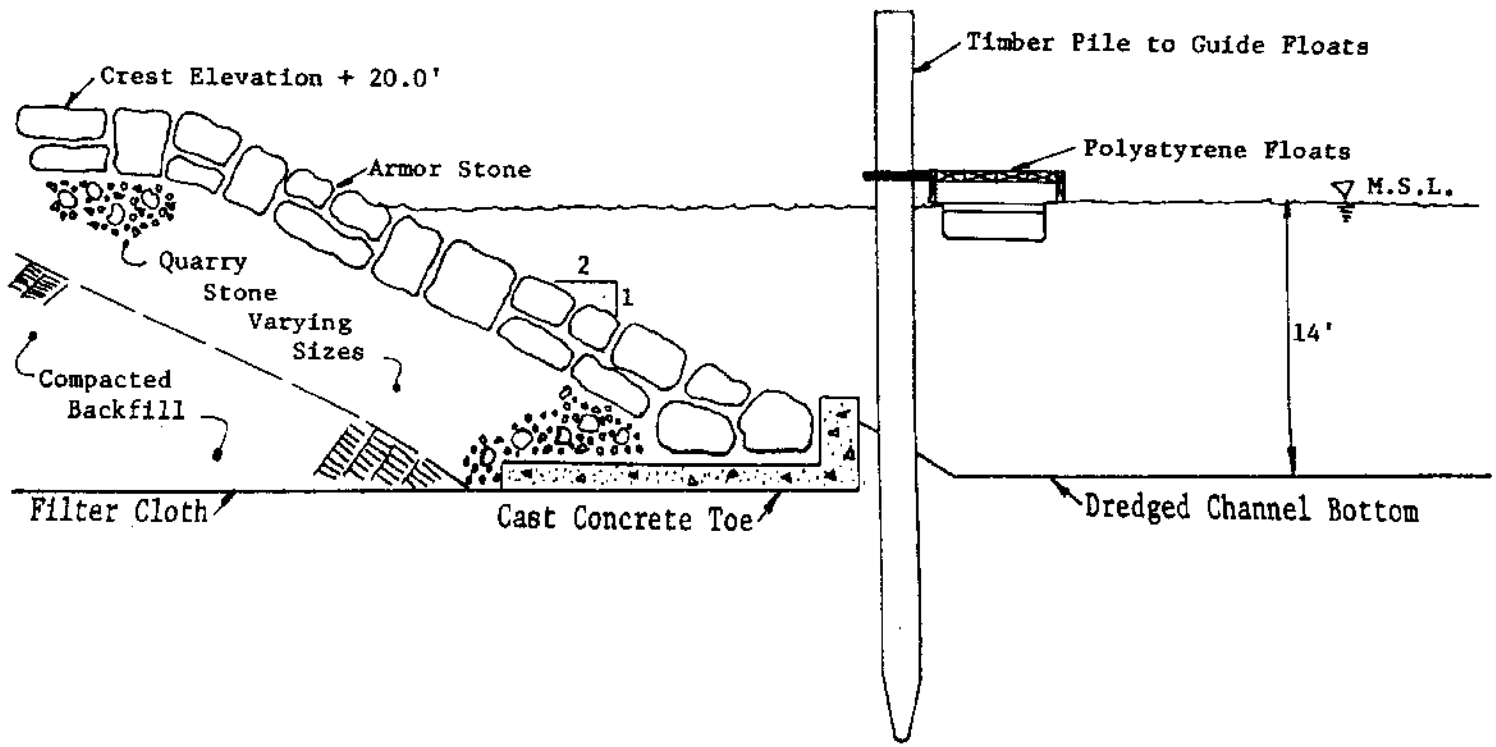


FIGURE 18: SECTION THROUGH CHANNEL RIP-RAP PROTECTION

toe will keep the armor stone from shifting. Quarry-run stone under the armor stone will insure that fine material is not washed out through the armor stone due to wave action.

At mean sea level the surface area of armor stone exposed to organic activity is $\sqrt{5} \times 14' = 31.2$ feet per foot of length. Since the armor stone is randomly placed, not fitted, the contact area available is actually much greater than just this one surface. Assume a factor of 4 to compute the available surface. The total length of channel protection in the marina is approximately 3950 linear feet (from figure 17); therefore the total available contact area due to the rip-rap is 5.05×10^5 ft^2 (3950' x 31.2' x 4). The total available area between floats and rubble mound sea wall is 5.34×10^5 ft^2.

It was assumed earlier that fouling production is 1500 g/m^2, while marsh grass produces 1000 g/m^2. In Chapter 5, it was explained that if fouling production was 1.5 times the production of an area of marsh, then the two systems would be equal, at least in useful food produced. In our case, therefore, we require equal areas between the fouling contact surface and the replaced marshland. The area of marsh lost was 7.2×10^5 ft^2, while the area gained for fouling production is 5.34×10^5 ft^2 in the marina. This means that in comparison to the marshland the marina, as designed, is 75% efficient in food production. If the new marshland created with the dredge spoil is counted, the combined production (fouling on floats and rip-rap and marsh grass from new marshland) would represent 134% efficiency, or a 34% increase in food production over the displaced marsh.

To achieve this production in the marina, it is essential that a sewage collection system be implemented. The site chosen has low tidal amplitudes and is far removed from an existing sewer line or treatment facility. Therefore, in accordance with the discussion presented in Chapter 5, the design of the collection system will depend upon these factors. The following are the important elements of the marina's sewage collection system:

1. wastewater discharge from all buildings will be collected along with waste from watercraft;
2. all recreational watercraft equipped with toilet facilities will have holding tanks onboard to collect wastes;
3. sewage collection stations will be located at the sites indicated on Figure 17. Each station will have a flexible hose connection with a macerator pump to relieve the pleasurecraft holding tanks. The pumps are supplied by the marina operator to avoid tampering and abuse of pumps onboard individual pleasurecraft. Also a single station avoids the necessity of supplying a connection at each berth;

4) a collection system attached to the floats made of corrosion-resistant piping (P.V.C. piping has been recommended[17] because it is cheap and easy to install and lends itself easily to flexible connections at breaks in the float system). This piping will take the wastes from the pumps to the underwater collection tanks moored in the surge basin;

5) a metering system on the collection piping will tell the marina operator when to switch over to another tank and have the full one emptied;

6) the waste will be pumped from the underwater tanks either to tank trucks for transportation to an existing treatment facility or directly to an on-site treatment facility in which case the storage tanks would serve to even out peak weekend and holiday flows over the entire week.

The composite design presented above is only a functional design for a compatible marina - marsh system. Further study is necessary before we can be certain that the implementation of each guideline will be carried out. The flushing system should be modeled either in the lab or on a computer to determine the exact behavior of the flow in the marina for different tidal amplitudes and channel configurations. Model studies will also be helpful for resonant frequency analysis of the marina basin, coastal erosion and deposition, and general circulation pattern changes in and around the new marina. Experiments in artificial marsh construction should be undertaken to determine under what conditions the marsh will re-establish itself. It must be determined how attractive the rip-rap sidewalls are to marine organisms, where the populations are the most abundant and why. And finally a push should be made for legislation making control of wastes from watercraft mandatory and, more important, uniform for all marinas in every state.

CHAPTER 7
CONCLUSIONS

In this report, guidelines for marina development in a marsh environment have been proposed in order to preserve biological production. It has been found that it is possible to match the biological production of the two sites in two possible ways, outside and within the marina. The first method requires that dredge spoil from marina construction be placed in estuarine waters in such a way that a new marsh re-establishes itself on the organically rich spoil. The second method requires tailoring the marina environment to make it attractive to biological production by fouling communities, an alternative to marsh grass as a source of food. The marina is made attractive by flushing pollutants out with each tidal cycle, maintaining high water quality by waste collection and providing a surface on which the organisms can prosper and multiply.

Examples were given as to how these guidelines could be implemented for new marina construction. The application of these methods to any new marina development would of course involve a technological study of specific site requirements, but the guidelines here presented will provide an outline around which new marinas can be developed to provide the minimum environmental impact and the greatest harmony between man and nature.

LIST OF REFERENCES

1. Conservation Foundation. Pollution By Pesticides. Washington, D.C.: By the Author, 1250 Connecticut Ave. N.W., 1969.

2. Daiber, Franklin C., et al. Environmental Impact of Dredge and Fill Operations in Tidal Wetlands Upon Fisheries Biology in Delaware. Unpublished Report to Division of Fisheries and Wildlife, Department of Natural Resources and Environmental Control, State of Delaware, University of Delaware: December 22, 1972.

3. Davidson, Paul; Adams, F. Gerald; and Seneca, Joseph. "The Social Value of Water Recreation Facilities Resulting From an Improvement in Water Quality: The Delaware Estuary," Water Research, Baltimore: John Hopkins Press, 1966.

4. Eisenberg, Wilbert S. "Environmental Aspects of Jacksonville Harbor Project," Journal of the Waterways, Harbors, and Coastal Engineering Division, A.S.C.E., Volume 99, May, 1973.

5. Elliot, Glenn K. The Great Marsh, Lewes, Delaware. Newark, Delaware: University of Delaware, College of Marine Studies, December, 1972.

6. Environmental Protection Agency, Water Quality Office, Technical Support Division. The Economic and Social Importance of Estuaries. Estuarine Pollution Study Series 2, Washington, D.C.: U.S. Government Printing Office, April, 1971.

7. Gulf and Caribbean Fisheries Institute. Proceedings of the 19th Session, Sept. 1967. "A Biologist's Viewpoint of Man-Made Change in Estuaries" By George W. Allen.

8. Gullidge, Ellsworth J. and Urabeck, Frank J. "Planning for Pleasure Boating on Regional Basis," Journal of the Waterways, Harbors and Coastal Engineering Division, A.S.C.E., Volume 96, August, 1970.

9. Hitchcock, Stephen W. "Fragile Nurseries of the Sea - Can We Save Our Salt Marshes?," National Geographic Magazine, Volume 141, No. 6, June, 1972.

10. Isard, Walter. Ecologic-Economic Analysis for Regional Development. New York: The Free Press, 1972.

11. Lockwood, Mason G. and Carothers, Henry D., "Preservation of Estuaries by Tidal Inlets," Journal of Waterways and Harbors Division, A.S.C.E., November, 1967.

12. New York Times. Article, Page 1 "Birth, Fertility Rates at New Low in U.S." By Harold M. Schmeck, Jr., April 6, 1974.

13. Nixon, Scott W.; Oviatt, Candace A.; and Northby, Sharon L. Ecology of Small Boat Marinas, Marine Technical Report Series No. 5, Kingston, R.I.: University of Rhode Island, 1973.

14. Task Committee on Small Craft Harbors, Committee on Ports and Harbors, Waterways and Harbors Division. Report on Small Craft Harbors. New York, N.Y.: American Society of Civil Engineers, 1969.

15. Teal, John and Mildred. Life and Death of the Salt Marsh. New York, N.Y.: An Audubon/Ballantine Book, 1969.

16. United States Congress, Report by the Secretary of the Interior. The National Estuarine Pollution Study. Washington, D.C.: U.S. Government Printing Office, 1970.

17. U.S. Department of Interior, Federal Water Pollution Control Administration, Northwest Region, Technical Proj. Branch. Houseboat Wastes - Methods for Collection and Treatment. By B. D. Clark, Washington, D.C.: U.S. Government Printing Office, June, 1967.

18. U.S. Department of Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries. National Estuary Study. Volume 2, Washington, D.C.: U.S. Government Printing Office, January, 1970.

19. U.S. Department of Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries. National Estuary Study. Volume 4, Washington, D.C.: U.S. Government Printing Office, January, 1970.

20. U.S. Department of Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries. National Estuary Study. Volume 5, Washington, D.C.: U.S. Government Printing Office, January, 1970

21. U.S. Department of Interior, Federal Water Pollution Control Administration. Collection, Underwater Storage and Disposal of Pleasurecraft Waste. By Underwater Storage Inc. and Silver, Schwartz, Ltd., Joint Venture. Washington, D.C.: U.S. Government Printing Office, September, 1969.

22. U.S. Department of Interior, Federal Water Pollution Control Administration. Waste From Watercraft. Senate Document No. 48 Washington, D.C.: U.S. Government Printing Office, August, 1967.

Cover design: Lorraine Turner