A summary report

Bay and Estuarine System Management in the Texas Coastal Zone

Division of Planning Coordination
Office of the Governor

March 1973

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BAY AND ESTUARINE SYSTEM MANAGEMENT IN THE TEXAS COASTAL ZONE

Prepared for

OFFICE OF THE GOVERNOR
DIVISION OF PLANNING COORDINATION
COASTAL RESOURCES MANAGEMENT PROGRAM
INTERAGENCY COUNCIL ON NATURAL RESOURCES
AND THE ENVIRONMENT
STATE OF TEXAS

by

THE DIVISION OF NATURAL RESOURCES AND THE
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INTRODUCTION

The anticipated future growth of population and industry in Texas' coastal zone will have a significant effect on the natural resources within the area. Growth pressures generally increase environmental pollution. Already many of the 368 waste treatment plants and 171 solid waste disposal sites do not meet State standards.

The State must develop and maintain a coordinated plan for judicial management of the air, land, water, mineral and biological resources along the coast. The Legislature directed the Interagency Council on Natural Resources and the Environment to conduct a comprehensive study and submit recommendations by December, 1972.

A multi-disciplinary research team at The University of Texas was formed at the request of the Governor's Office. They were charged with delineating the various aspects of an analytical approach for effective management of the coastal zone. This requires enumeration of the various uses of coastal resources; determination of the interrelationships between and resultant effects of those uses; and, finally, development of operational guidelines for effective management of the coastal zone.

The multi-disciplinary team formed was composed of specialists in geology, engineering, water quality, biology, and ecomomics. Affected State agencies provided additional input. All conclusions were considered by all members of the team. All output is related. The analytical framework developed is not structured by individual discipline - it is an integrated whole.

The introductory phase of the team's effort was completed during the summer of 1971. This phase was aimed at developing a systematic approach to understanding problems relative to the bays and estuaries. This approach is discussed in detail in a preliminary report, "Conceptual Report - The Management of Bay and Estuarine Systems."

Only the essence of the analytical framework developed during this first phase is summarized in this report.

This report summarizes the first phase of the work on developing guidelines for managing the coastal zone and the analytical framework developed.

ANALYTICAL APPROACH

The analysis was developed by delineating broad management components and relating the components.

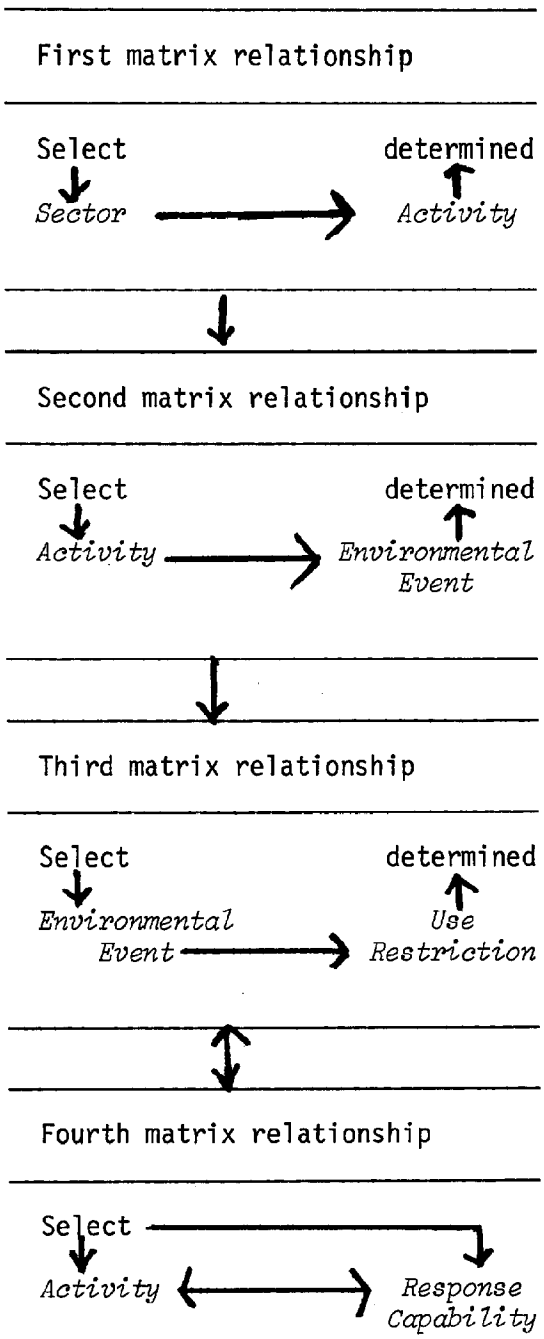
A brief introduction to the five components and their relationship will assist the reader in understanding the analytical approach presented herein.

The five components are:

- *Sectors* - socioeconomic causes of man's coastal zone activities.
- *Coastal zone activities* - physical activities in the coastal zone that affect the environment.
- *Environmental events* - physical, biological and geological events resulting from man's activities and which affect the water, air, land or biological processes.
- *Use restrictions* - restrictions in coastal use resulting from a change in an environmental event.
- *Resource capability units* - coastal and land units grouped according to their limitations and characteristics with respect to use.

Each component is a set of items. These items are displayed and the relationships between items in components are established through the use of matrices. The use of matrices is illustrated opposite.

The analytical approach presented herein is demonstrated through the use of matrices. This illustration is presented to introduce to the reader the matrices and their relationships as explained in the following sections. Note the flow goes from "select" to "determined" and then to the next matrix.



SECTORS AND COASTAL ZONE ACTIVITIES

The first of the five components in this analytical approach is the *sector*.

Sectors are the broad socio-economic causes of man's physical activity in the coastal zone.

Man lives along the coast. He uses it. He extracts minerals and crops from the land; fish and other marine life from the water. He transports produce to manufacturing plants. He builds houses in the area and utilities to supply electricity, gas, water and other amenities.

For this analysis the term *sector* is used to describe why man uses the coast. They describe the extractive, transportation, manufacturing and other functions which man does on the coast.

Seventeen sectors were identified by the multi-disclinary team after an extensive review of information. The 17 *sectors* so identified are:

1. Shell fishing
2. Fin fishing
3. Surface mining
4. Subsurface mining
5. Irrigated agriculture
6. Mariculture
7. Other agriculture
8. Navigation
9. Ports
10. Pipelines
11. Highways, railroads, airports
12. Electric and gas utilities
13. Water supply and wastewater treatment
14. Recreation
15. Non-manufacturing
16. Manufacturing
17. Residential construction

In our analytical approach the next question is, what specific physical activities are necessary to support each sector of development?

Coastal Zone Activities

Coastal zone *activities* are the second component in the analytical approach.

Physical *activities*, stemming from the various sectors, directly affect the coastal environment.

Man's growth patterns in the coast may be forecasted. Man's *activities* undertaken in support of, or in response to, this growth pattern can be determined. Disposing of wastes, construction of structures both on land and in the bay, and draining lowland are part of these activities.

The term *activity* in this analysis is used to describe how man changes the coastal resources. They are a response to the socio-economic sectorial development along the coast.

Seventeen coastal zone activities have been identified. They are:

1. Liquid waste disposal
2. Gaseous waste disposal
3. Solid waste disposal
4. Offshore construction
5. Coastal construction
6. Inland construction
7. Land canals
8. Offshore channels
9. Dredging and spoil disposal
10. Excavation
11. Drainage
12. Filling
13. Draining
14. Well development
15. Devegation
16. Traversing with vehicles
17. Use of fertilizers and biocides

These activities are the result of sectorial development. On the opposite page the interaction between the itemized sectors and the itemized activities are discussed and presented in matrix form.

SECTORS AND ACTIVITIES
INTERACTION MATRIX 1

In the matrix below is displayed the qualitative interactions between the 17 sectors and coastal zone activities. A marked cell indicates a significant relationship. An unmarked cell indicates an insignificant relationship. Starting with sectors, the activities are identified from this matrix.

This matrix is generally the starting point in our analytical approach. After the coastal zone activities have been identified, Matrix 2 is used to determine the environmental events resulting from these activities.

SECTORS \ COASTAL ZONE ACTIVITIES	1. Liquid Waste Disposal	2. Gaseous Waste Disposal	3. Solid Waste Disposal	4. Offshore Construction	5. Coastal Construction	6. Inland Construction	7. Land Canals	8. Offshore Channels	9. Dredging and Spoil Disposal	10. Excavation	11. Drainage	12. Filling	13. Draining	14. Well Development	15. Devegetation	16. Traversing With Vehicles	17. Use of Fertilizers and Biocides
1. Shell Fishing	●		●		●												
2. Fin Fishing	●				●												
3. Surface mining					●	●	●		●	●			●		●		
4. Subsurface Mining	●	●	●	●	●	●			●	●			●	●	●		
5. Irrigated Agriculture						●	●				●		●	●	●		●
6. Mariculture	●				●	●				●	●		●				●
7. Other Agriculture	●		●			●					●	●	●		●		●
8. Navigation				●	●	●	●	●	●			●				●	
9. Ports	●		●	●	●	●	●	●	●			●	●				
10. Pipelines					●	●	●		●	●					●	●	
11. Highways, Railroads & Airports	●	●	●		●	●				●	●	●	●		●		
12. Electric and Gas Utilities	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	
13. Water Supply & Wastewater Treatment	●	●	●		●	●	●		●	●	●	●	●	●			
14. Recreation	●		●		●	●				●	●	●	●		●	●	●
15. Non-Manufacturing	●	●	●		●	●											
16. Manufacturing	●	●	●	●	●	●	●	●		●	●	●	●	●			
17. Residential Construction	●		●		●	●				●		●	●		●		

MATRIX 1

COASTAL AREA ACTIVITIES AND ENVIRONMENTAL EVENTS

The third of the five components in this analytical approach to coastal management is the *environmental event.*

Environmental events result from man's physical activities. *Events* are grouped according to whether the change affects the water (water quality), the air (air quality), the earth (a physical process), or the biota (a biological process.)

The term *environmental event* in this analysis refers to the actual factor or environmental condition being changed.

Twenty-seven *environmental events* were identified by the research team, those are:

1. BOD
2. Dissolved Oxygen
3. Nutrients
4. Pathogens
5. Floatables
6. Odors and Tastes
7. Color
8. Toxicity
9. Dissolved Salts
10. Suspended Solids
11. Radiological
12. Temperature
13. Ph Buffering
14. Groundwater
15. Particulates
16. Gases
17. Erosion
18. Deposition and Accretion
19. Subsidence
20. Hydraulics
21. Devegetation
22. Infiltration
23. Ponding
24. Photosynthesis
25. Consumers/Food Chain
26. Decomposition
27. Predation

Once the environmental events have been identified, the most logical step is to determine the relationship between the event and its effect on the beneficial uses of the bays and estuaries of the coast. If the beneficial use of the coastal resources are impaired, the proper actions can be taken.

ACTIVITIES AND EVENTS INTERACTION MATRIX 2

In the matrix on the opposite page is displayed the qualitative interactions between the 17 coastal zone activities and the 27 environmental events. A marked cell indicates a significant relationship; an unmarked cell, a insignificant relationship. Starting with *activities*, the *events* are identified from this matrix.

This matrix is generally used after the activities have been identified through the use of Matrix 1. After the events have been identified, Matrix 3 is used to determine the use restrictions resulting from these events.

ENVIRONMENTAL EVENTS / ACTIVITIES	WATER QUALITY														AIR QUALITY		PHYSICAL PROCESSES							BIOLOGICAL PROCESSES			
	1. BOD	2. Dissolved Oxygen	3. Nutrients	4. Pathogens	5. Floatables	6. Odors and Tastes	7. Color	8. Toxicity	9. Dissolved Salts	10. Suspended Solids	11. Radiological	12. Temperature	13. Ph Buffering	14. Ground Water	15. Particulates	16. Gases	17. Erosion	18. Deposition and Accretion	19. Subsidence	20. Hydraulics	21. Devegetation	22. Infiltration	23. Ponding	24. Photosynthesis	25. Consumers/Food Chain	26. Decomposition	27. Predation
1. Liquid Waste Disposal	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●		●	●	●	●
2. Gaseous Waste Disposal															●	●					●			●	●	●	●
3. Solid Waste Disposal	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●				●	●	●	●	●	●	●	●
4. Offshore Construction	●	●						●		●							●	●		●				●	●	●	●
5. Coastal Construction	●	●							●	●							●	●		●	●			●	●	●	●
6. Inland Construction	●	●								●				●			●	●		●	●	●	●	●	●	●	●
7. Land Canals									●	●		●		●			●	●		●	●	●	●	●	●	●	●
8. Offshore Channels									●	●		●					●	●		●	●			●	●	●	●
9. Dredging and Spoil Disposal	●	●	●			●	●	●	●	●		●	●				●	●		●	●	●	●	●	●	●	●
10. Excavation										●				●			●	●			●	●	●	●	●	●	●
11. Drainage	●	●	●	●	●	●	●	●	●	●	●	●	●	●			●	●		●	●	●	●	●	●	●	●
12. Filling										●				●			●	●		●	●	●		●	●	●	●
13. Draining	●	●	●		●	●	●		●	●		●	●	●			●	●	●	●	●	●		●	●	●	●
14. Well Development									●					●					●			●		●	●	●	●
15. Devegetation	●	●	●							●				●			●	●		●	●	●		●	●	●	●
16. Traversing With Vehicles	●	●			●	●	●	●		●					●	●	●	●			●			●	●	●	●
17. Fertilizers/Biocides	●	●	●					●						●	●						●			●	●	●	●

MATRIX 2

ENVIRONMENTAL EVENTS AND USE RESTRICTIONS

The fourth component in this analytical approach is the *use restriction.*

Possible *use restrictions* result from environmental events stemming from man's activities.

Some environmental events result in a reduction of or impairment to certain beneficial uses of the coastal resources. Fish and wildlife resources may be depleted because of reduction in water quality or interruption of the biologic food chain process.

The term *use restriction* is used to describe the actual resource uses which are subject to restrictions because of a particular environmental event, or condition, has occurred.

Determining possible *use restrictions* is an important aspect in managing bay and estuarine systems along the Texas coast. It is particularly useful for determining environmental impacts caused by development along the coast.

The multi-disciplinary team identified nine major uses that man can make of bays and estuaries. There are:

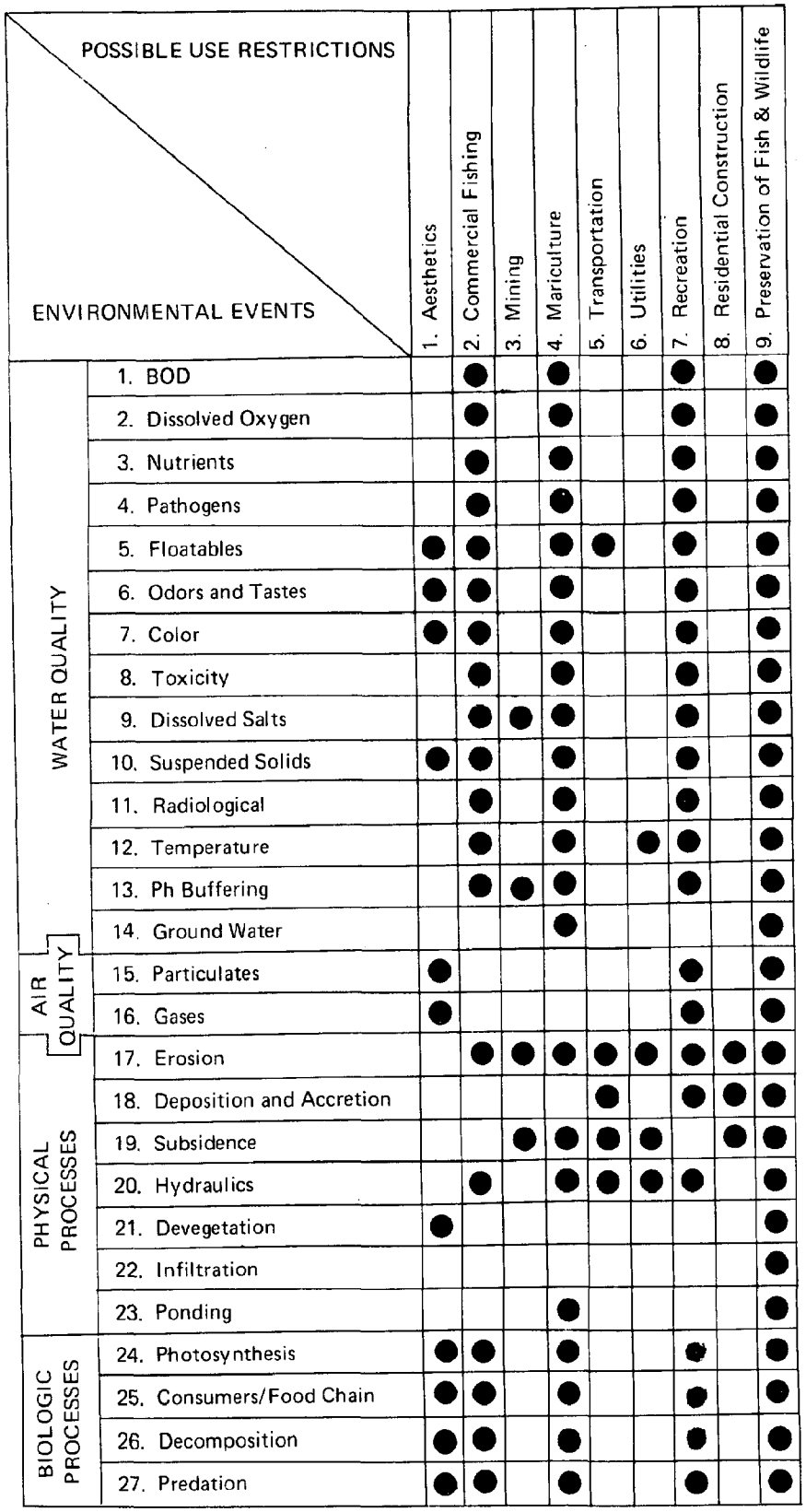
1. Aesthetics
2. Commercial Fishing
3. Mining
4. Mariculture
5. Transportation
6. Utilities
7. Recreation
8. Residential Construction
9. Preservation of Fish and Wildlife

FIRST ASPECT OF ANALYTICAL APPROACH

Development of an understanding of man's impact on the coastal resources through extensive analysis of the relations between *sectors, activities, environmental events* and *uses* is the first aspect of this analytical approach. These four components have been shown in the previous three sections. The complete chain of interrelationships between them are demonstrated in the last section entitled "Example."

EVENTS AND USES RESTRICTIONS INTERACTION MATRIX 3

In the matrix on the opposite page is displayed the qualitative interactions between the 27 environmental events and the 9 possible use restrictions. A marked cell indicates a significant relationship; an unmarked cell indicates an insignificant relationship. Starting with *events*, the *use restrictions* are identified through the use of Matrices 1 and 2. Identification of these use restrictions and an understanding of the interaction's relationships between the four components encompassed in these three matrices constitutes the major part of this analytical approach. Matrix 4 is used to show the interactions between land and water resource capability and man's activities.



POSSIBLE USE RESTRICTIONS RESULTING FROM ENVIRONMENTAL EVENTS

MATRIX 3

ACTIVITIES AND RESOURCE CAPABILITY UNITS

The fifth and last major component in this analytical approach to coastal management is the land and water resource capability unit.

Land and water *resource capability units* are simply coastal lands and water dominated lands, which are classified primarily according to factors which control or limit land-water use.

Coastal resources management guidelines depend to a great degree upon:

1) Recognition and delineation of proper land and water units,
2) Determination of their actual and limiting characteristics, properties and capabilities, and
3) Understanding the relationships between man, the units and capability of the units.

To accomplish this over 130 environmental geologic land and water units were defined and delineated. These were grouped into 34 resource capability units based primarily upon their limiting capabilities.

Among the many factors taken into account in establishing resource capability units are topography; soil type; process-defined units such as tidal pass areas, beaches and stream channels; biologic assemblages of specific plant and animal population such as benthonic communities, and man-made units such as spoil heaps and dredged channels. Other considerations include potential for flooding, erosion and drainage; permeability and impermeability; groundwater availability and many other factors.

The 34 *resource capability units* encompass six major capability classes as shown in the listing in Matrix 4 on the following page.

SECOND ASPECT OF ANALYTICAL APPROACH

The first aspect or part of this analytical approach relates sectors, activities, environmental events and use restrictions.

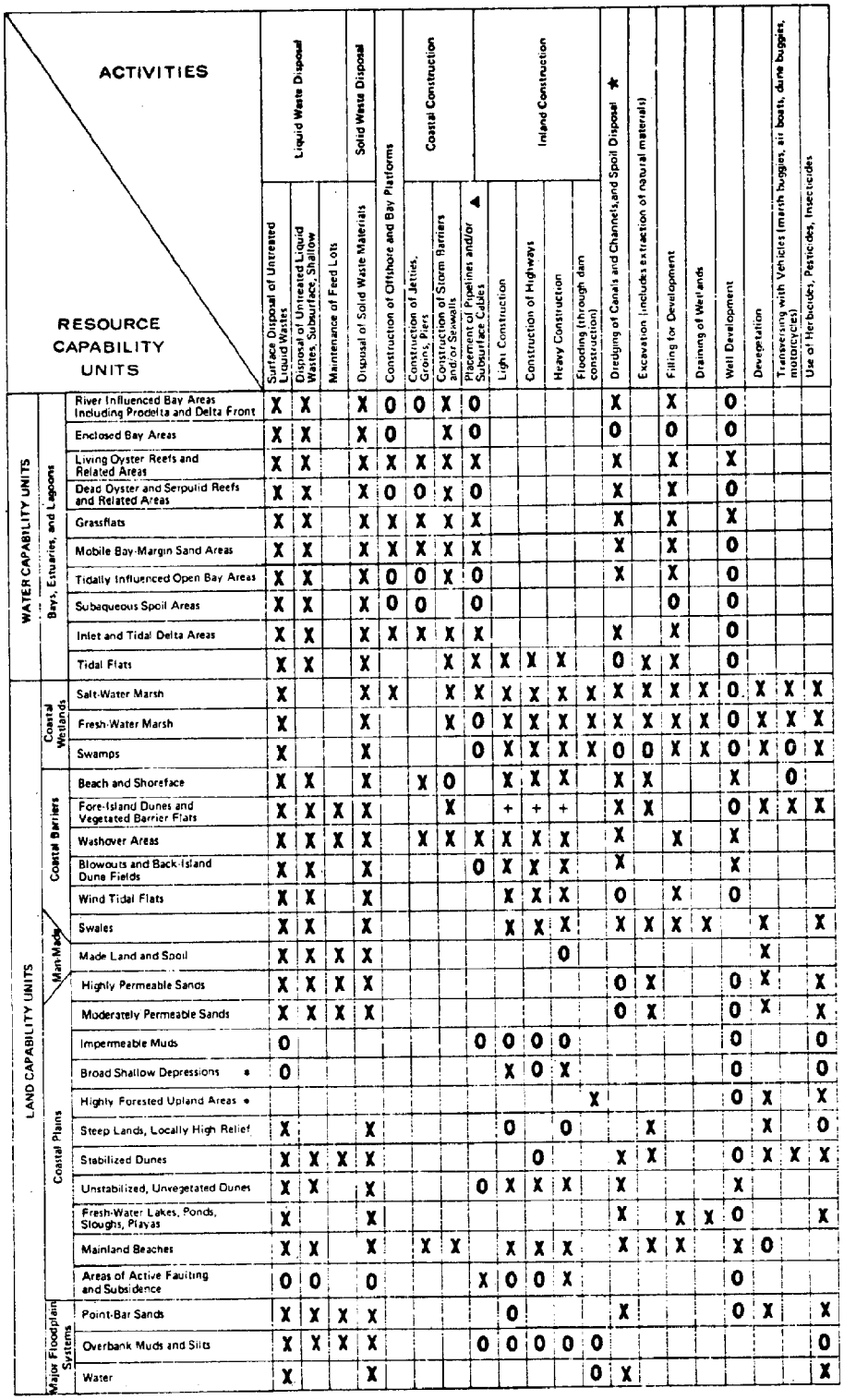
The other major aspect of this analytical approach is to provide a guide for determining the relationships or interactions between man's activities and resource capability units. This knowledge enables detailed examination of these activities or sectorial development.

ACTIVITIES AND RESOURCE CAPABILITY UNITS INTERACTION MATRIX 4

In Matrix 4 on the following page is displayed the qualitative interactions between the resource capability units and man's activities in the coastal zone. A marked cell indicates a significant relationship; an unmarked cell indicates activities do not take place or do not cause a problem.

This matrix can be used independently of the other three matrices, or they can be used in combination.

Of most interest in analyzing coastal problems is the relationship between *resource capability units* and sectorial development along the coast. These interactions can be determined through the use of Matrix 1 in combination with Matrix 4, as shown in the following section.



X Undesirable (will require special planning and engineering)
O Possible problem(s)
+ Barrier Flat only (no construction on dunes)

▪ Substrate variable
▲ Also occurs in Offshore Construction
★ Also occurs in Offshore Canals and Dredging

MATRIX 4

EXAMPLE

The previous sections have described the nature and content of each individual matrix. This section illustrates through the use of a decision tree concept how these individual elements can be used together to analyze a specific problem. The following example shows how the analytical method could be used for designing the ecological studies necessary to prepare an environmental impact statement on a particular problem.

PROBLEM STATEMENT

Assume an environmental impact statement must be prepared on a proposed oyster shell dredging operation where the shell is in shallow water and overlain by a thin layer of silt and sand. Except for a few oil wells and limited recreational facilities the estuary is undeveloped. Thus, the matrices will be used together to make a preliminary determination of what detailed scientific studies may be needed to develop an acceptable environmental impact statement. Additionally, this cursory analysis should provide some initial qualitative insight into how the system functions.

PROCEDURE

The analytical flow is as follows:

1. Enter Martix 1 with sector and obtain resultant man's activities.
2. Enter Matrix 2 with these activities and exit with likely environmental events and determine what uses might be impaired.

Subjective decisions which are heavily dependent upon the analyst's knowledge of the specific problem and situation, are necessary at each step.

For our example enter Matrix 1 along row three "surface mining." Moving across we find "o's" in seven columns representing coastal construction, (5) inland construction (6), land canals (7), dredging and spoil disposal (13) and devegetation (15). This simply informs us that if we are to have the development of shell dredging, which falls under the sector classification "surface mining," then we might expect to have man engaging one, several or possibly all of these activities.

While for any specific case one is not likely to engage in all seven, he is apt to carry on more than one of them. In order to set the entire process in perspective, we will introduce a new concept called a "decision tree." This is a conceptually simple graphical analytical tool for illustrating a sequential decision process, where each decision presents a new array of possibilities, but excludes others.

The accompaning figure is a decision tree for this example. One begins on the left-hand side in the box entitled "surface mining." It is then straightforward to follow this branch into seven limbs, each corresponding to the seven possible activities of man listed above. Five of these now terminate whereas the other two continue to branch out. The five that terminated were inland construction (6), land canals (7), excavation (10), draining (13) and devegetation (15). In making these terminations, the analyst must be problem-specific and use his own judgement. In this hypothetical case, neither of these possible activities were applicable because the mining operation is well out in the bay, thus activities such as devegetation, draining, excavation, land canals and inland construction would not occur.

The next step in the analysis consists of determining what environmental events are likely to be triggered by each of the two applicable man's activities. Matrix 2 is used to determine this. One begins with the two applicable coastal zone activities (5 and 9) and scans the rows across each of these headings. This reveals that each of these activities can possibly produce many environmental events. In fact, collectively they trigger 20 of the 27 possible events as shown on the decision tree. In some

cases, both activities may cause the same event, but in others only one may do so.

Decisions again must be made based on the specific set of circumstances at hand. The list of events caused by each activity is carefully scrutinized using the best information available and the researcher's experience. Those environmental events that are judged to be significant are retained for consideration, and the others are dropped. An investigation of the branching portions under the heading "Environmental Events" on the tree shows all possible events resulting from both coastal construction and dredgings and spoil disposal. The ones considered insignificant terminate with an "x" while the others branch still further. Those that continue are suspended solids (10), deposition/accretion (14), photosynthesis (24) and consumers/food chain (25). It is important that the branches representing the two activities of coastal construction and dredging and spoil disposal are still kept separate. This is done because while both may generate suspended solids, they will do so in different approaches to quantify the load and its action mechanism.

The next step is the determination of what uses of the bays and estuaries may be impaired by these significant environmental events as shown in Matrix 3.

For our example, those potential impairments may include aesthetics (1), commercial fishing (2), mariculture (4), transportation (5), recreation (7), residential construction (8), and the preservation of fish and wildlife (9). Once these have been revealed, we can complete our "assignment" in this particular problem: the delineation of the necessary scientific investigations. By utilizing the information gained through this analysis, we can conclude that we should channel our limited energies along the following lines:

Step 1: Man's Activities

1. Perform modeling experiments to gain a knowledge of the hydrodynamic behavior of the estuary under various conditions.

2. Conduct field experiments to determine the natural patterns of sediment distribution under typical conditions.

3. Couple the two in order to obtain the best available picture of the most likely sediment distribution patterns.

Step 2: Environmental Events

1. Analysis should include special provisions for determining the impact of the altered transport processes upon the natural phenomena of deposition and accretion.

2. The potential sediments should be carefully analyzed in order to determine their potential nutrient contribution to the estuarine system.

3. The impact on photosynthesis and decomposition from nutrient release, sedimentation, turbidity should be closely scrutinized.

Step 3: Potential Uses Impaired

1. Fish and wildlife maintenance may be significantly affected. Thus, studies should be done to determine things such as (a) how much nursery areas will be adversely affected by sedimentation process, (b) will the turbidity severely upset aquatic communities, and if so, over how big an area, and (c) what, if any, significant effects will nutrient release/alterations in the photosynthetic process have?

2. Trace the impact of the disturbances determined in the immediately preceding analysis in order to describe their effects on commercial and sports fishing.

3. Determine if the repercussions of the aggregate mining will be spatially widespread and severe enough to injure the bay's aesthetic amenities and recreation activities.

4. Compare the predicted sediment distribution patterns with existing navigation facilities and determine if such deposition will interfere with those arteries.

The above type of analysis will provide one with qualitative insights into the system functioning. Such knowledge should enable him to channel his efforts along the most crucial/significant routes possible in the next step, that of quantifying the interactions and effects.

The above example is an oversimplication. However, it should provide insight into how the qualitative relationships identified by the interdisciplinary team can be applied. Other examples have been explored. Unfortunately, space and time constraints do not permit their inclusion here.

SUPPLEMENT A

DESCRIPTION OF SECTORS

EXTRACTION

1. *Shell Fishing*
   Shell fishing may involve waste disposal (1, 3) and may result in coastal construction such as piers, docks and processing plants (5).

2. *Fin Fishing*
   The only coastal zone activities that can be directly related to fin fishing are coastal construction of facilities such as piers, docks and processing plants (5) and liquid waste disposal from processing plants (1).

3. *Surface Mining*
   Surface mining of oyster shell generally involves excavation (10) which in turn may result in devegetation (15) and may require inland construction (6) and draining (13).

4. *Subsurface Mining*
   Subsurface mining requires well development (14). Also it may require offshore construction such as platforms (4), coastal or inland construction (5, 6), dredging and spoil disposal such as to put in platforms (9), excavation such as brine pits (10), and filling and draining (12, 13) may result in devegetation (15), and results in liquid, gaseous and solid wastes (1, 2, 3).

5. *Irrigated Agriculture*
   Irrigated agriculture requires the construction of land canals (7), inland construction such as dykes, pumping facilities (6) and devegetation (15) may involve well development (14), draining of low lying areas (13) and drainage projects (11). Of particular concern is the application of fertilizers and biocides (17) and the runoff of these materials into rivers, bays and estuaries.

6. *Mariculture*
   Mariculture generally involves drainage alterations (11), draining (13), excavation (10) and application of fertilizers and biocides (17). It may also result in coastal and inland construction of related facilities (5, 6) and in liquid waste disposal (1).

7. *Other Agriculture*
   Other agriculture generally involves devegetation (15), application of fertilizers and biocides (17), inland construction (6) and drainage alterations, filling and draining (11, 12, 13). Animal feed lot operations result in both liquid and solid waste disposal (1, 3).

TRANSPORTATION

8. *Navigation*
   Navigation might involve offshore channels (8), offshore, coastal and inland construction (4, 5, 6), inland canals (7) and traversing with vehicles (16). It might also involve dredging and spoil disposal (9) and filling (12).

9. *Ports*
Port construction offshore might involve development of offshore channels (8), offshore construction (4) and dredging and spoil disposal (9). Construction of ports onshore usually involves development of land canals (7), coastal and inland construction (5, 6), filling (12) and draining (13). The operation of any port would increase liquid and solid waste disposal (1, 3).

10. *Pipelines*
Development of pipelines involves offshore construction (4), coastal construction (5), inland construction (6), dredging (9), and might involve excavation (10), devegetation (15) and traversing with vehicles (16).

11. *Highways, Railroads and Airports*
Expansion or development of highways creates additional auto traffic resulting in gaseous wastes (2).

Construction of highways, railroads and airports involves excavation (10), drainage (11), filling (12), draining (13), inland construction (6), coastal construction (5) and devegetation (15).

Expansion or development of airports creates additional air traffic resulting in increased gaseous wastes (2). In addition, airport operation results in liquid and solid wastes (1, 3).

UTILITIES

12. *Electric and Gas Utilities*
Development and expansion of electric and gas utilities involves liquid, gaseous and solid waste disposal (1, 2, 3). Construction of electric and gas utilities, including both production and distribution facilities, might involve offshore construction (4), offshore channels (8), dredging and spoil disposal (9), coastal and inland construction (5, 6), land canals (7), excavation (10), drainage (11), filling (12), draining (13), devegetation (15) and traversing with vehicles (16).

13. *Water Supply and Wastewater Treatment*
Water supply and wastewater treatment involve liquid, gaseous and solid waste disposal (1, 2, 3). Construction of water supply and wastewater treatment might involve coastal and inland construction (5, 6), land canals (7), dredging and spoil disposal (9), excavation (10), drainage (11), filling (12), draining (13) and well development (14).

RECREATION

14. *Recreation (includes Contact and Non-Contact Recreation)*
Recreation involves liquid and solid waste disposal (1, 3).

Some forms of recreation may involve traversing with vehicles such as motorboats, mini bikes, dune buggies (16).

Development and expansion of recreation may require coastal and inland construction (5, 6).

Reservoir construction to provide recreation opportunities might involve excavation (10), drainage (11), filling (12), draining (13) and devegetation (15).

Improvement of fish and wildlife habitat might involve the use of fertilizers and biocides (17).

OTHER

15. *Nonmanfacturing (includes Services and Trade, Banking, Insurance and Commerce)*
Development or expansion of nonmanufacturing might involve liquid, gaseous and solid waste disposal (1, 2, 3).

Development or expansion of nonmanufacturing might involve coastal and inland construction (5, 6).

16. *Manufacturing (includes all SIC's listed in Table 1)*
Development or expansion of manufacturing might involve liquid, gaseous and solid waste disposal (1, 2, 3).

Development or expansion of manufacturing might involve offshore, coastal and inland construction (4, 5, 6), land canals (7), offshore channels (8), excavation (9), drainage (10), filling (12), draining (13) and well development (14).

17. *Residential Construction*
Development or expansion of residential construction involves liquid and solid waste disposal (1, 3).

Development or expansion of residential construction involves coastal and inland construction (5, 6) and related excavation (10), filling (12), draining (13) and devegetation (15).

SUPPLEMENT B

DESCRIPTION OF MAN'S COASTAL ACTIVITIES

WASTE DISPOSAL

1. *Liquid Waste Disposal*
   Disposal of any waste in liquid form into the environment

2. *Gaseous Waste Disposal*
   Disposal of gaseous waste into the environment

3. *Solid Waste Disposal*
   Disposal of solid wastes into the environment

CONSTRUCTION

4. *Offshore Construction*
   Construction in bays and estuaries, continental shelf

5. *Coastal Construction*
   Construction on shoreline and shallow waters, barrier islands and fish passes

6. *Inland Construction*
   Construction in coastal plain

CANAL DEVELOPMENT

7. *Land Canals*
   Land cuts which disrupt shoreline or immediately adjacent coastal plain

8. *Offshore Channels*
   Canals in bays and estuaries and cuts through barrier islands

9. *Dredging and Spoil Disposal*
   Relocation of bottom sediments or shell from natural environments; relocation of sediments from any type of channelization

10. *Excavation*
    On land relocation of soil

11. *Drainage (runoff)*
    Alteration of natural drainage systems affecting runoff

12. *Filling*
    Placing of solid materials into low lying areas

13. *Draining*
    Removing water from low lying areas (such as marshes)

14. *Well Development*
Includes petroleum, sulfur, natural gas, salt, and water extraction and injection

15. *Devegetation*
Destruction or alteration of natural vegetation

16. *Traversing with Vehicles*
Dune buggies and other offroad vehicles and boats not used for navigation and commercial activities

17. *Fertilizers and Biocides*
Application on land or water of fertilizers and biocides

SUPPLEMENT C

DESCRIPTION OF ENVIRONMENTAL EVENTS RESULTING FROM MAN'S ACTIVITIES

WATER QUALITY

1. *Biochemical Oxygen Demand (BOD)*
When organic materials undergo aerobic biological degradation, the decomposing organisms require oxygen in order to function. This is called BOD and exerts a demand on the dissolved oxygen (DO) resources of the water body. Most BOD arises from waste disposal (1, 3) but some comes from construction and related activities (4, 5, 6, 9, 11, 13, 15), certain agricultural practices (17)*, and boats (16).

2. *Dissolved Oxygen (DO)*
The DO of a water body usually drops because of the input of soluable and solid oxygen demanding materials as discussed under BOD above (1, 3, 4, 5, 6, 9, 11, 13, 15, 16, 17). Other actions/processes affecting the DO level include water temperature, reaeration, dissolved salts, and upsets in the photosynthesis-respiration cycle.

3. *Nutrients*
Most nutrient inputs (such as nitrogen and phosphorus) result from waste disposal (1, 3). Normal secondary wastewater treatment does not remove significant portions of these substances. Certain activities (9, 11, 13) and the use of fertilizers (17) may change the nutrient concentration. Devegetation (15) would aid the input of nutrients by erosion.

4. *Pathogens*
These usually come from the disposal of wastes (1,3) but may also result from river drainage (11).

5. *Floatables*
Improper waste disposal (1, 3), as well as runoff (11), reclamation (13), and excessive vehicular activity (16) can generate inputs of floatables in the bays and estuaries.

6. *Odors and Tastes*
These most generally result from waste disposal (1, 3), but can also result from certain construction-related activities (9, 11, 13) and vehicles (16).

7. *Color*
Possible sources of color are about the same as for odors and tastes, namely waste disposal (1, 3) and others (9, 11, 13, 16).

8. *Toxicity*
Toxic materials may be extremely varied in nature, including both organic and inorganic materials, some of which quickly degrade while others are extremely persistent. Most common sources are waste disposal (1, 3), agriculture (17) and drainage (11). Construction activity (4, 9) may introduce some toxic substances.

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*Other possible sources for BOD loadings do exist, but the reader should recall that while this analysis is general, it is oriented toward Texas' bays and estuaries. Thus, its nature reflects the collective knowledge of its authors toward that specific situation.

9. *Dissolved Salts*
Well development (14), certain construction work (5, 7, 8, 9, 11, 13), waste disposal (1, 3) account for all significant contributions of dissolved salts.

10. *Suspended Solids*
Almost any activity of man in, or adjacent to the bays and estuaries can result in the introduction of suspended solids into the estuarine system. Chief contributors are virtually any kind of construction and related activity (4, 5, 6, 7, 8, 9, 10, 12, 13, 15), waste disposal (1, 3), drainage (11) and vehicular activity (16).

11. *Radiological*
The most likely results from waste disposal (1, 3) but could also be transported into the estuarine system by the natural process of run-off such as drainage (11).

12. *Temperature*
Liquid wastes (1), including cooling water, can produce significant, localized temperature changes. Other activities which alter the basic physical configuration or flow regimes (7, 8, 9, 11, 13) of bays may also alter the natural temperature conditions.

13. *PH Buffering*
Alternations of this phenomenon are most likely to result from waste disposal (1, 3), inland construction and related activities (6, 7, 10, 11, 12, 13, 15), well development (15) and certain agricultural practices.

14. *Groundwater* **
Groundwater resources can be adversely affected by waste disposal (1, 3), inland construction and related activities (6, 7, 10, 11, 12, 13, 15), well development (15) and certain agricultural practices.

AIR QUALITY

15. *Particulates*
Waste disposal operations (1, 2, 3) account for much of the atmospheric particulates, whether these be industrial facilities, residential trash burning or transportation operations. Some construction (6) traversing with vehicles (16), and agricultural practices (17) may make additional contributions.

16. *Gases*
Most gaseous materials which are released into the atmosphere are the waste (1, 2, 3) by-products from some combustion process, be it an industrial or a private automobile (16).

**The quality parameters discussed in the above 13 sub-sections can all apply to some degree to groundwater as well as surface water. Since our primary concern in this report is bay and estuarine management, the discussion of groundwater is greatly abbreviated.

PHYSICAL PROCESSES

17. *Erosion*
Almost any endeavor of man, be it waste disposal (1) or virtually any form of activity (4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16) alters any part of the physical environment, can, if unwisely done, trigger devastating erosion.

18. *Deposition and Accretion*
Like erosion, almost anything that man does in or adjacent to estuarine areas, may upset the natural balance between these processes (1, 4, 5, 6, 7, 8, 9, 10, 11, 13, 15, 16).

19. *Subsidence*
The overpumpage of water supply aquifers (14) is the most common cause of subsidence. However, in certain cases some has been blamed on oil production (14). The draining of wetlands (13) may also contribute to localized subsidence.

20. *Hydraulics*
The hydraulics or flow regime of an estuarine system can be altered by waste (1, 3) inputs if their flow is sufficient. Most common changes occur as a result of construction and related practices (4, 5, 6, 7, 8, 9, 11, 12, 13, 15) which change the original flow patterns.

21. *Devegetation*
Loss of surface cover can result from improper waste disposal (1, 2, 3), certain construction and related practices (5, 6, 7, 8, 9, 10, 11, 12, 13, 15) vehicular activity (16) and agricultural endeavors (17).

22. *Infiltration*
Improper waste disposal (1, 3) certain construction and related activities (6, 7, 9, 10, 11, 12, 13, 15) and faulty well development (14) may result in infiltration of undesirable substances into a good aquifer.

23. *Ponding*
Ponding may result from certain construction and related activities (6, 7, 9, 10, 11) or poor solid waste disposal practices (3).

BIOLOGICAL PROCESSES

24. *Photosynthesis*

25. *Consumers/Food Chain*

26. *Decomposition*

27. *Predation*
Almost each physical activity has an effect on the various biological processes. Hence, man must institute environmental controls so that these processes are not significantly upset or provide an altered environment in which these biological processes perform functions that provide greater socioeconomic benefits to man than the original environment.

SUPPLEMENT D

DESCRIPTION OF POSSIBLE USE RESTRICTIONS

1. *Aesthetics*
The aesthetic value of a bay or estuary may be adversely affected in a direct manner by any substances altering its appearance such as floating materials (5), unusual color (7), or high turbidity due to suspended solids. Likewise, unusual odors and tastes (6) are undesirable. A significant change, either natural or man-induced, in any biological process (24, 25, 26, 27) may impair the aesthetic value. Also, air pollution (15, 16) and devegetation (21) are undesirable from an aesthetic point of view.

2. *Commercial Fishing*
This usage may be affected by any significant surface water quality change (1-13). Alteration of bay and estuarine circulation patterns caused by significant changes in freshwater inflow, barrier island passes, and dredging or spoil deposition adversely affects commercial fishing (20). Water quality and circulation patterns are affected by erosion processes (17). Naturally commercial fishing productivity is a function of the four major biological processes (24, 25, 26, 27).

3. *Mining*
Dissolved solids (9) and pH buffering (13) could possibly impair this use if water was needed for secondary recovery operations. Certain physical processes (17, 19) could also have an adverse effect.

4. *Mariculture*
The lowering of quality conditions (1-14) and some physical processes (17, 19, 20, 23) could affect biological phenomena upon which a mariculture operation is based.

5. *Transportation*
Changes in a number of physical processes (17, 18, 19, 20) could severely impair transportation if not properly attended to. Floatables (5) are the only water quality conditions likely to impair a water body's utility as a transportation medium, and then only under extremely rare conditions.

7. *Recreation*
Recreational uses which cover a broad spectrum ranging from fishing to contact sports to boating can be impaired by most water quality conditions (1-13). All biological processes (24, 25, 26, 27) play a significant role as to certain physical processes (17, 18, 20) and air pollution (15, 16).

8. *Residential Construction*
Indirectly residential construction may be adversely affected by any environmental event which reduces the aesthetic or recreation uses of a water or land resource. However, the only direct effects come from certain physical processes (17, 18, 19).

9. *Preservation of Fish and Wildlife*
Virtually any environmental change (1-27) may affect the use of a resource for the preservation of fish and wildlife. However, if properly managed these changes could be beneficial rather than harmful.

SUPPLEMENT E

BIOLOGICAL USE CRITERIA

The accompanying table contains a tentative list of possible biological use criteria for coastal waters. These numbers are tentative, and to some degree speculative. They were developed in a short period of time using available hard data and the judgement of the researchers. Since their initial formulation, detailed scientific investigations have been undertaken in an attempt to develop more substantial criteria.

TABLE B-8

Biological Use Criteria

	Threshold Limits
Salinity	±10% of maximum and minimum over 5 year average
Sulfates	10% above maximum average for total 5 years
Dissolved solids	±10% of maximum and minimum over 5 year average
BOD-organic carbon	One order of magnitude above primary product carbon over 5 years
O_2	2.5 ppm
pH	6.5 - 8.5
Coliforms	10,000/100 ml.
Temperature	4° - September - May 1.5° - June - August less than above ambient
Toxicants	(See specific compounds)
Solids & Turbidity	5000 mg/l.
Radio nuclides: Strontium Gross Beta Radium 226	 10 pc/l. 1000 pc/l. 3 pc/l.
Color	No restriction except due to chemical composition
Taste & Odor	Organoliptical absent *in situ*
Phenols	1.0 mg/l
Alkyl-Aryl Sulfonates	1.0 mg/l
Pesticides	10 ug/l
Oil	No visible sheen
Detergents, cationic	1 ug/l

Trace elements:	mg/l*	mg/l**
Mercury	.00003	.01
Copper	.003	.01
Lead	.00003	.05
Nickel	.0054	.05
Zinc	.01	5.00
Chromium	.00005	1.00
Cadmium	.08	.10
Arsenic	.003	1.00
Silver	.0003	.01
Variadium	.002	1.00
Fluorine	1.30	10.00
Cyanide	--	.02
Manganese	.002	.10
Cobalt	.0005	.01
H_2S	variable	.50
Beryllium	.0000006	.001
Selenium	.004	.01
Ytrium	.0003	.01
Antimony	.0005	.01
Boron	4.6	10.00

*mg/l - *normal oceanic seawater*

**mg/ - *threshold limits*