Biological Services Program

FWS/OBS-77/14
March 1978

Environmental Planning for Offshore Oil and Gas

Volume III:

Effects on Living Resources and Habitats

Fish and Wildlife Service

U.S. Department of the Interior

[illegible] program was established within the [illegible] Fish [illegible] information and methodologies on [illegible] issues that impact fish and wildlife resources and their [illegible]. The [illegible] of the program is as follows:

- [illegible] the Fish and Wildlife Service in its role as [illegible] information on national fish and wild[life] [illegible], particularly with respect to environmental [illegible].

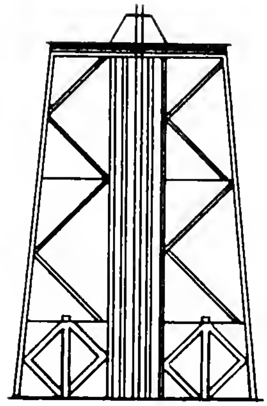
- [illegible], analyze, and [illegible] information that will [illegible] [illegible] and resolution of [illegible] land and water [illegible].

- [illegible] evaluation [illegible] the [illegible] programs [illegible] relating to energy development.

[illegible] the [illegible] Services [illegible] [illegible] [illegible]. Research activities and [illegible] analysis of the issues [illegible] and their information needs, [illegible] the state of the art [illegible] information gaps, [illegible] that will [illegible] that [illegible].

[illegible] [illegible] stream alterations and western [illegible] National Wetland Inventory, [illegible] transfer.

[illegible] of Biological [illegible] overall planning and [illegible] the [illegible] central scientific [illegible] contracting Biological Services [illegible], and others. Regional [illegible] operating levels, and staff at [illegible] facilities, who conduct inhouse research [illegible].



FWS/OBS-77/14
March 1978

Environmental Planning for Offshore Oil and Gas

Volume III: Effects on Living Resources and Habitats

by

John Clark and Charles Terrell

The Conservation Foundation
1717 Massachusetts Avenue, N.W.
Washington, D.C. 20036

Contract No. 14-16-0008-962

Larry Shanks, Project Officer
National Coastal Ecosystems Team
National Space Technology Laboratories
NSTL Station, Mississippi, 39529

Performed for
National Coastal Ecosystems Team
Office of Biological Services
Fish and Wildlife Service
U.S. DEPARTMENT OF THE INTERIOR

Environmental Planning for Offshore Oil and Gas

Volume I: Recovery Technology

Volume II: Effects on Coastal Communities

Volume III: Effects on Living Resources and Habitats

Volume IV: Regulatory Framework for Protecting Living Resources

Volume V: Regional Status Reports:

Part 1: New England

Part 2: Mid and South Atlantic

Part 3: Gulf Coast

Part 4: California

Part 5: Alaska, Washington and Oregon

This report should be cited thusly:

Clark, J. and C. Terrell. 1978. Environmental Planning for Offshore Oil and Gas. Volume III: Effects on Living Resources and Habitats. The Conservation Foundation, Washington, D.C. U.S. Fish and Wildlife Service, Biological Services Program. FWS/OBS-77/14. 220 pp.

ENVIRONMENTAL PLANNING FOR OFFSHORE OIL AND GAS

FOREWORD

This report is one in a series prepared by The Conservation Foundation for the Office of Biological Services of the U.S. Fish and Wildlife Service (Contract 14-16-0008-962). The series conveys technical information and develops an impact assessment system relating to the recovery of oil and gas resources beyond the three-mile territorial limit of the Outer Continental Shelf (OCS). The series is designed to aid Fish and Wildlife Service personnel in the conduct of environmental reviews and decisions concerning OCS oil and gas development. In addition, the reports are intended to be as helpful as possible to the public, the oil and gas industry, and to all government agencies involved with resource management and environmental protection.

Oil and gas have been recovered for several decades from the Outer Continental Shelf of Texas, Louisiana and California. In the future, the Department of the Interior plans to lease more tracts, not only off these coasts, but also off the frontier regions of the North, Mid- and South Atlantic, eastern Gulf of Mexico, Pacific Northwest and Alaska. Within the set of constraints imposed by the international petroleum market (including supply, demand and price), critical decisions are made jointly by industry and government on whether it is advisable or not to move ahead with leasing and development of each of the offshore frontier areas. Once the decision to develop a field is made, many other decisions are necessary, such as where to locate offshore platforms, where to locate the onshore support areas, and how to transport hydrocarbons to market.

Existing facilities and the size of the resource will dictate which facilities will be needed, what the siting requirements will be, and where facilities will be sited. If the potential for marketable resources is moderate, offshore activities may be staged from areas already having harbor facilities and support industries; therefore, they may have little impact on the coast adjacent to a frontier area. An understanding of these options from industry's perspective will enable Fish and Wildlife Service personnel to anticipate development activities in various OCS areas and to communicate successfully with industry to assure that fish and wildlife resources will be protected.

The major purpose of this report is to describe the technological characteristics and planning strategy of oil and gas development on the Outer Continental Shelf, and to assess the effects of OCS oil and gas operations on living resources and their habitats. This approach should help bridge the gap between a simple reactive mode and effective advanced planning--planning that will result in a better understanding of the wide range of OCS activities that directly and indirectly generate impacts on the environment, and the countermeasures necessary to protect and enhance living resources.

Development of offshore oil and gas resources is a complex industrial process that requires extensive advance planning and coordination of all phases from exploration to processing and shipment. Each of hundreds of system components linking development and production activities has the potential for adverse environmental effects on coastal water resources. Among the advance judgements that OCS planning requires are the probable environmental impacts of various courses of action.

The relevant review functions that the Fish and Wildlife Service is concerned with are: (1) planning for baseline studies and the leasing of oil and gas tracts offshore and (2) reviewing of permit applications and evaluation of environmental impact statements (EIS) that relate to facility development, whether offshore (OCS), near shore (within territorial limits), or onshore (above the mean high tidemark). Because the Service is involved with such a broad array of activities, there is a great deal of private and public interest in its review functions. Therefore, it is most valuable in advance to have some of the principles, criteria and standards that provide the basis for review and decisionmaking. The public, the offshore petroleum industry, and the appropriate Federal, state, and local government agencies are thus able to help solve problems associated with protection of public fish and wildlife resources. With advanced standards, all interests should be able to gauge the environmental impacts of each OCS activity.

A number of working assumptions were used to guide various aspects of the analysis and the preparation of the report series. The assumptions relating to supply, recovery, and impacts of offshore oil and gas were:

1. The Federal Government's initiative in accelerated leasing of OCS tracts will continue, though the pace may change.

2. OCS oil and gas extractions will continue under private enterprise with Federal support and with Federal regulation.

3. No major technological breakthroughs will occur in the near future which could be expected to significantly change the environmental impact potential of OCS development.

4. In established onshore refinery and transportation areas, the significant impacts on fish and wildlife and their habitats will come from the release of hydrocarbons during tanker transfers.

5. A significant potential for both direct and indirect impacts of OCS development on fish and wildlife in frontier areas is expected from site alterations resulting from development of onshore facilities.

6. The potential for onshore impacts on fish and wildlife generally will increase, at least initially, somewhat in proportion to the level of onshore OCS development activity.

The assumptions related to assessment of impacts were:

1. There is sufficient knowledge of the effects of OCS development activities to anticipate direct and indirect impacts on fish and wildlife from known oil and gas recovery systems.

2. This knowledge can be used to formulate advance criteria for conservation of fish and wildlife in relation to specific OCS development activities.

3. Criteria for the protection of environments affected by OCS-related facilities may be broadly applied to equivalent non-OCS-related facilities in the coastal zone.

The products of this project--reported in the series Environmental Planning for Offshore Oil and Gas--consist of five technical report volumes. The five volumes of the technical report series are briefly described below:

Volume I — Reviews the status of oil and gas resources of the Outer Continental Shelf and programs for their development; describes the recovery process step-by-step in relation to existing environmental regulations and conservation requirements; and provides a detailed analysis for each of fifteen OCS activity and facility development projects ranging from exploration to petroleum processing.

Volume II — Discusses growth of coastal communities and effects on living resources induced by OCS and related onshore oil and gas development; reports methods for forecasting characteristics of community development; describes employment characteristics for specific activities and onshore facilities; and reviews environmental impacts of probable types of development.

Volume III — Describes the potential effects of OCS development on living resources and habitats; presents an integrated system for assessment of a broad range of impacts related to location, design, construction, and operation of OCS-related facilities; provides a comprehensive review of sources of ecological disturbance for OCS related primary and secondary development.

Volume IV — Analyzes the regulatory framework related to OCS impacts; enumerates the various laws governing development offshore; and describes the regulatory framework controlling inshore and onshore buildup in support of OCS development.

Volume V — In five parts, reports current and anticipated OCS development in each of five coastal regions of the United States: New England; Mid and South Atlantic: Gulf Coast; California; and Alaska, Washington and Oregon.

John Clark was The Conservation Foundation's project director for the OCS project. He was assisted by Dr. Jeffrey Zinn, Charles Terrell and John Banta. We are grateful to the U.S. Fish and Wildlife Service for its financial support, guidance and assistance in every stage of the project.

William K. Reilly
President
The Conservation Foundation

ENVIRONMENTAL PLANNING FOR OFFSHORE OIL AND GAS

PREFACE

This report provides basic information for advance assessment of the effects of outer continental shelf oil and gas recovery on fish and wildlife resources and their supporting ecosystems. It encompasses offshore recovery operations, onshore facilities development, and the transport of raw and processed hydrocarbons.

The material is presented within a framework designed to clarify and facilitate the assessment process for all parties involved. The content of the report is explained in Part I, Introduction, and Part 2, Impact Assessment, which should be carefully studied. It is a highly structured document based upon a specially developed systematic approach to impact assessment. It is styled for use as a reference source rather than as a reader.

While the report is designed to stand on its own, the user will find the companion volumes in this series to be most helpful in providing both a broader context for assessment and considerably more detailed descriptions of various aspects of the recovery of offshore oil and gas.

John Clark
Charles Terrell

TABLE OF CONTENTS

ENVIRONMENTAL PLANNING FOR OFFSHORE OIL AND GAS

VOLUME III: EFFECTS ON LIVING RESOURCES AND HABITATS

Page

Page

Page

Page

Page

LIST OF TABLES

Table		Page

LIST OF FIGURES

Figure		Page

Figure		Page

ABBREVIATIONS

BBL	Barrels
B/D	Barrels per day
BLM	Bureau of Land Management
BTU	British Thermal Unit
BOD	Biochemical oxygen demand
CALM	Catenary anchor leg mooring
CAPLINE	Central American Pipeline System
COD	Chemical oxygen demand
COST	Continental Offshore Stratigraphic Test
DEIS	Draft Environmental Impact Statement
DO	Dissolved oxygen
DWT	Dead Weight Tons
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ERDA	Energy Research and Development Administration
FCC	Federal Communications Commission
FEA	Federal Energy Administration
FIA	Federal Insurance Administration
FWS	U.S. Fish and Wildlife Service
GPD	Gallons per day
GPO	U.S. Government Printing Office
HUD	U.S. Department of Housing and Urban Development
kwh	Kilowatt hour

kwh/month	Kilowatt hours per month
kwh/year	Kilowatt hours per year
lbs/day	Pounds per day
LNG	Liquefied natural gas
LOOP	Louisiana Offshore Oil Port
LOT	Load on top
ml	Milliliter
MMGD	Million gallons per day
mm	Millimeters
MMCFD	Million cubic feet per day
MPN	Most probable number (of coliform bacteria)
MSL	Mean sea level
NEPA	National Environmental Policy Act
NGPSA	National Gas Pipeline Safety Act
NPDES	National Pollution Discharge Elimination System
OCS	Outer Continental Shelf
OSHA	Occupational Safety and Health Administration
PCB	Polychlorinated biphenyl
ppm	Parts per million
SALM	Single anchor leg mooring
SPM	Single point mooring
TCF	Trillion cubic feet
USGS	U.S. Geological Survey
VLCC	Very Large Crude Carrier

CONVERSION TABLE

	Multiply number of	by	to obtain equivalent number of
Length	Inches (in)	25·4	millimetres (mm)
		2·54	centimetres (cm)
	Feet (ft)	30·48	centimetres
		0·3048	metres (m)
	Yards (yd)	0·9144	metres
	Fathoms (6ft)	1·8288	metres
	Miles (land 5,280 ft)	1·609344	kilometres (km)
	Miles (UK sea 6,080 ft)	1·853184	kilometres (km)
	Miles, international nautical	1·852	kilometres (km)
Area	Sq inches (in²)	645·16	sq millimetres (mm²)
		6·4516	sq centimetres (cm²)
	Sq. feet (ft²)	929·0304	sq centimetres
		0·092903	sq metres (m²)
	Sq yards (yd²)	0·836127	sq metres
	Acres	4,046·86	sq metres
		0·404686	hectares (ha)
		0·004047	sq kilometres (km²)
	Sq miles	2·58999	sq kilometres
Volume and capacity	Cu inches (in³)	16·387064	cu centimetres (cm³)
	UK pints	34·6774	cu. inches
	UK pints	0·568	litres (l)
	UK gallons	4·546	litres (l)
	US gallons	3·785	litres (l)
	Cu feet (ft³)	28·317	litres (l)
	Cu feet	0·028317	cu. metres (m³)
	UK bushels	0·3637	hectolitres (hl)
	US bushels	0·3524	hectolitres (hl)
	UK gallons	1·20095	US gallons
	US gallons	0·832674	UK gallons
	UK bulk barrels	36	UK gallons
		43·2342	US gallons
		0·1637	cu. metres
Weight (mass)	Grains (gr)	64·79891	milligrams (mg)
	Ounces avoirdupois (oz)	28·3495	grams (g)
	Ounces, troy (oz tr)	31·1035	grams (g)
	Ounces, avoirdupois	0·9115	ounces, troy
	Pounds, avoirdupois (lb)	453·59237	grams
		0·45359	kilograms (kg)
	Hundredweights (cwt) (112 lb)	0·05	long tons
		0·508023	metric quintals (q)
	Short tons (2,000 lb)	0·892857	long tons
		0·907185	tonnes (t)
	Long tons (2,240 lb)	1·12	short tons
		1·01605	tonnes

	Multiply number of	by	to obtain equivalent number of
Length	Millimetres	0·03937	inches
	Centimetres	0·3937	inches
	Metres	39·3701	inches
		3·2808	feet
		1·0936	yards
		0·54681	fathoms
	Kilometres	0·62137	miles (land)
		0·53961	miles (UK sea)
		0·53996	miles, international nautical
Area	Sq millimetres	0·00155	sq inches
	Sq centimetres	0·1550	sq inches
	Sq metres	10·7639	sq feet
		1·19599	sq yards
	Hectares	2·47105	acres
	Sq kilometres	247·105	acres
		0·3861	sq. miles
Volume and capacity	Cu centimetres	0·06102	cu. inches
	Litres	61·024	cu inches
		0·0353	cu feet
		0·2642	US gallons
		0·2200	UK gallons
	Hectolitres	26·417	US gallons
		21·997	UK gallons
		2·838	US bushels
		2·750	UK bushels
	Cu metres	35·3147	cu. feet
		1·30795	cu yards
		264·172	US gallons
		219·969	UK gallons
		6·11025	UK bulk barrels
Weight (mass)	Milligrams	0·01543	grains
	Grams	0·03527	ounces, avoirdupois
		0·03215	ounces, troy
	Kilograms	2·20462	pounds, avoirdupois
	Metric quintals	220·462	pounds, avoirdupois
	Tonnes	2,204·62	pounds, avoirdupois
		1·10231	short tons
		0·984207	long tons

ACKNOWLEDGEMENTS AND DATA SOURCES

Technical information on OCS oil and gas activities and related onshore facilities given in this report was derived from Volume I of this series, unless another source is specifically cited. The ecological information came from various Conservation Foundation reports, including Coastal Ecosystem Management (publisher John Wiley and Sons, Interscience, New York, 1977) unless another source is specifically cited. Also particularly useful was The Onshore Facilities Related to Offshore Oil and Gas Development Factbook (New England River Basins Commission for U.S. Department of the Interior, 1976).

Members of The Conservation Foundation staff who prepared this volume were John S. Banta and Jeffrey A. Zinn. John H. Noble assisted with general counsel and with detailed review, and Raymond L. Tretheway III was the principal research assistant. Other research assistants were Catherine Lochner, Duane Hampton, and Craig Richardson. Claudia Wilson supervised the artwork and layout, assisted by Deborah Sheinbrood. John O. Ludwigson, David C. Williams, and Oscar Strongin provided editorial and technical review. Laura O'Sullivan supervised typing and assembly of the manuscript.

Personnel of the Office of Biological Services who were particularly helpful were Drs. Allan Hirsch, William Palmisano, Howard Tait, and Donald Woodard. Larry Shanks of that office gave especially close attention to the preparation of this report.

PART 1. INTRODUCTION

The contents of this volume identify largely with procedures for environmental assessment in areas affected by offshore oil and gas recovery operations. In so doing, it lists oil and gas activities and facilities in standard terms, and categorizes them in detail with ecological disturbances and impacts.

The subject material is simplified by accepting the premise that the principles of environmental assessment are the same whether the issue concerns a permit review, a tract rejection, an evaluation of an environmental impact statement (EIS), or an informal appraisal of potential environmental impacts.

The material presented is a condensed reference source for ecological disturbances, and is structured to serve as a guide for impact assessment. References to a number of interrelated subjects, each of which is explained to the exclusion of other subjects, necessarily require repetitious material throughout Parts 3 and 4.

The four parts of this report and brief descriptions are as follow: Part I, Introduction; Part II, Impact Assessment, describes a recommended process for assessing impacts, identifies events that occur in sequence from development to impact, uses standardized nomenclature for assessment analysis, and recognizes ecological disturbances as the key element for assessing impacts; Part III, Generation of Disturbances by OCS Projects, reviews relevant data on ten types of OCS-related projects that may create ecological disturbances (the information is partly drawn from Volumes I and II of this series and the text is organized into project groups); Part IV, Potential Disturbances of Standard Subprojects, provides detailed review of ecological disturbances caused by OCS-related oil and gas development. The 20 subprojects were standardized to avoid extensive repetition regardless of the specific project for which the subproject is proposed.

Ecological effects of impact assessment are not traced out in detail in this volume because its purpose is to identify the sources of disturbance rather than to trace the effects through to impacts. The underlying assumption is that the reviewer or assessor has sufficient knowledge to predict the sequence from disturbance to effects, and from effects to impacts, after the distrubances are identified.

PART 2. IMPACT ASSESSMENT

Standardized procedures and nomenclature for impact assessments are invaluable for effective environmental analysis. A relatively sophisticated and useful method for determining oil and gas activity impacts is described here in detail and incorporates considerable information and terms developed in other volumes of this series. Although the method of impact prediction given here seems relatively complicated, careful examination of this section is likely to demonstrate that the method is relatively simple and highly useful, and is predicated on clearly evident elements in a framework of human activities and environmental impacts.

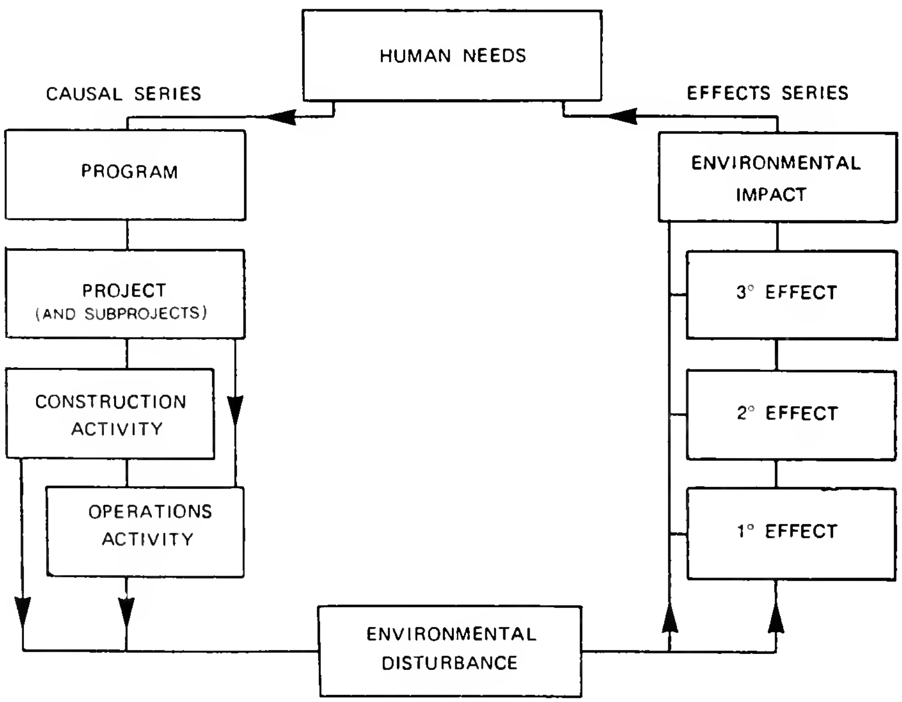
2.1 IMPACT TERMS AND CONCEPTS

To reduce misunderstanding and provide clarity, the elements of oil and gas activities and environmental analysis are categorized into a standard set of terms. These terms are explained in some of the following sections and those used in Part 2 of the text are usually underlined to eliminate need for further interpretation.

2.1.1 The Impact Cycle

The standard elements of impact assessment are linked in a change of causes and effects that starts with human needs and, at the end of the cycle, returns to human needs (Figure 1). The workings of the cycle become more apparent later in Part 2. The needs result in programs which lead to the initiation of specific development projects. These

Figure 1. An impact cycle, based on human needs, describing pathways of cause and effect.



projects are made up of component subprojects which are implemented by construction and operation activities. Any activity which leads to an environmental disturbance sets off a series of ecological effects. If these effects degrade the ecosystem, they cause an adverse impact that detracts from human needs. The elements of the cycle are defined in Table 1.

Table 1. Definition of the Cause and Effect Elements of the Impact Cycle

Element	Definition
Program	A broad initiative taken to fulfill some human need or needs such as offshore oil recovery, middle-income housing, or outdoor recreation.
Project	A specific physical element of a program such as a refinery, crew base, housing subdivision, or marina.
Subproject	A discrete physical component of a project such as site preparation, a bulkhead or pier.
Construction activity	An individual work process involved in the construction of a project facility such as land clearing or dredging.
Operations activity	An individual work process in the continuing operation of a project such as pumping oil or discharging wastes.
Environmental disturbance	An ecosystem perturbation caused by a disruptive activity such as a toxic discharge or elimination of wetlands.
Ecological effect	A reaction of an ecosystem to a disturbance such as oxygen depletion, turbidity, or siltation.
Environmental impact	An environmental alteration that affects the fulfillment of human needs.

For offshore oil and gas recovery programs, the chain begins with a direct or primary development project (e.g., a submerged pipeline or a platform fabrication yard). The component subprojects of OCS-related projects (e.g., individual initiatives such as navigation improvement channel or a bulkhead) are implemented with activities that are the same as those encountered in other waterfront or offshore work (e.g., dredging, pile driving). These activities cause disturbances that have recognized effects on fish and wildlife resources and their habitats. An example is given on the following page.

OCS PROJECT	SUBPROJECTS	ACTIVITIES	DISTURBANCES	EFFECTS
(e.g., platform yard)	(e.g., navigation, bulkheads)	(e.g.,dredging, pile driving)	(e.g.,disruption of bottom)	(e.g.,suspended solids, siltation)

OCS onshore development projects may stimulate secondary, or indirect, industrial development such as repair shops or equipment supply houses. Industrial development may also bring new residents who will require houses, stores, public utilities, schools, marinas and roads. Like the primary OCS projects, secondary development projects (e.g., construction of a marina for recreational boats) have component subprojects (e.g., docks) which require activities (e.g., depositing of spoil) which have effects on fish and wildlife resources and their habitats. A description of secondary development forecasting is outlined in Volume II of this report series, "Effects on Coastal Communities".

2.2 IMPACT ELEMENTS

The method of impact assessment recommended here requires: (1) the precise delineation of stages in the impact sequence to facilitate the assessment, and (2) detailed assessment of activity types with a known, or strongly suspected, potential for significant disturbance to natural resources, including fish and wildlife and their habitats.

2.2.1 Projects and Subprojects

Assessment begins with dividing the proposed project into component subprojects and then tracking each subproject through the impact cycle. The subproject is the smallest component of a project that typically would be recognized by an engineer as a discrete unit, such as a bulkhead, a pier, a stormwater system or the preparation of a site.

For convenience in assessing the effects of OCS-related activities on fish and wildlife, a set of standard subprojects has been compiled (Table 2). The choice of these particular subprojects reflects accommodation to several factors (such as relevance to OCS, intensity of effects, frequency of occurrence). These 20 standard subprojects are the framework for detailed consideration of disturbances in Part 4 of this report.

2.2.2 Activities

An activity is a work action--a bulldozer moving, a dragline dredging, or a pump discharging. The two major types of activities encountered in assessment are construction and operation. A subproject may have a potential for significant disturbance either in the construction or operational stage, depending upon the mix of activities involved. For example, a nearshore marine terminal may have a low potential for disturbance in construction, because pile driving is a relatively benign activity, but a high potential for disturbance in operation, because the transfer activity (from tankers to pipelines) may have a high probability of oil leaks and spills.

A list of common construction activities is given in Table 3. A list of operational activities (ongoing work of the subproject) is given in Table 4.

Terms have been standardized and are mutually exclusive to the extent possible.

In addition to constructionand operation, two other types of activities are recognized. First, choosing a location for a facility is an activity that precedes construction but is usually related to a project, not a subproject. Second, designing a subproject also precedes construction. The layout of units within a parcel is considered to be an aspect of design.

2.2.3 Disturbances and Effects

Activities that lead to perturbations of the environment, or disturbances, may trigger a complex sequence of effects. The effect series is made up of a number of elements that proceed from one to another and that often interact or feed back. For simplicity, Figure 1 shows only three stages, or orders, of effects. At times the linkage may be longer and more involved. At other times it is simple and the effect series is short-circuited; for example, land clearing (construction activity) may lead directly to extensive freshwater dilution of an estuary from rapid stormwater runoff (disturbance) and cause salinity reduction (effect) which results in a mass death of edible clams (impact) or detriment to mankind, the loss of the clam resource, comes from the first-order effect, dilution.

Usually the sequence of effects that lies between disturbance and impact has more similarity to a web than to a chain because of the interactions and feedbacks. Often a profusion of effects leads directly from a single disturbance. Conversely, a number of separate disturbances may multiply a single effect. A typical array of effects is illustrated in Figure 2.

Table 2. Standard Subprojects for Use in Impact Assessment of OCS-Related Primary and Secondary Development

Subproject Number	Subproject Title
SP-1	Navigational Improvement
SP-2	Piers
SP-3	Bulkheads
SP-4	Beach Stabilization
SP-5	Site Preparation
SP-6	Site Development
SP-7	Artificial Watercourses and Water Bodies
SP-8	Roadways and Bridges
SP-9	Groundwater Supply
SP-10	Sewage Systems
SP-11	Overland Transmission Systems
SP-12	Stormwater Systems
SP-13	Solid Waste Disposal
SP-14	Industrial Wastewater Systems
SP-15	Industrial Cooling Water Systems
SP-16	Pest Control
SP-17	Dikes and Levees
SP-18	Offshore Platforms and Structures
SP-19	Marine Transport of Oil
SP-20	Submerged Transmission Systems

Figure 2. A typical linkage showing the web of disturbances and effects leading to environmental impact from dredging (Source: Reference 1).

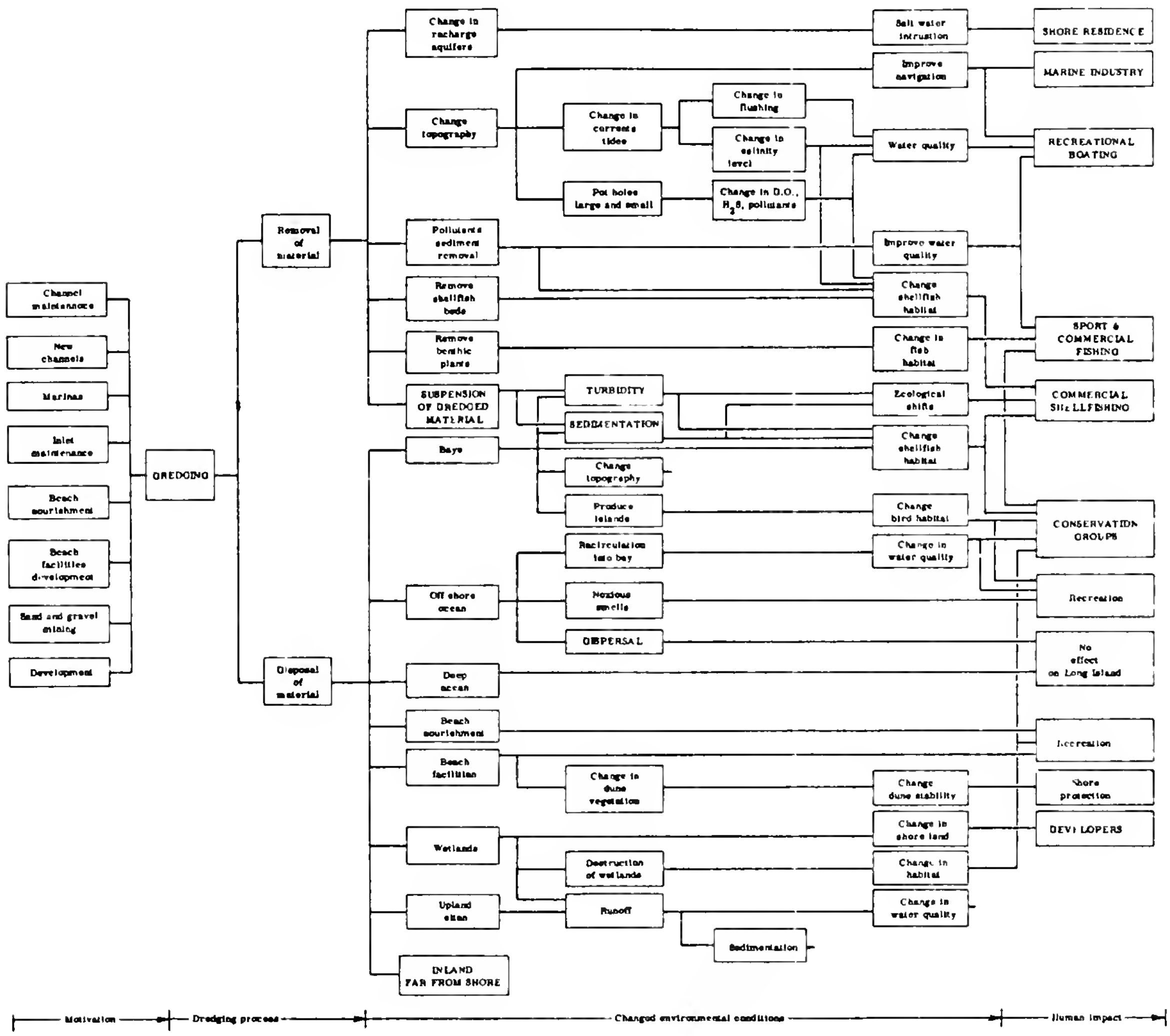


Table 3. Terms Used for OCS-Related Construction Activities in the Selective Assessment Method

Construction Activity	Construction Activity
Aggregate Removing	Land Surface Grading
Canal Excavation	Line Construction
Concrete Pouring	Oil and Gas Drilling
Dredging	Paving
Dune Stabilization	Pile Driving
Earth Moving	Pile Jetting
Excavation	Pile Placing
Facility Installation	Spoil Deposits
Fill Deposits	Structure Erection
Fill Removal	Submerged Line Laying
Land Drainage	Trenching
Land Surface Clearing	Water Well Drilling

Comprehensive analysis of all elements of this complex type of pattern may be difficult even for a knowledgeable scientist. Although such expert understanding occasionally may be required in the assessment of certain large and controversial projects, much of the routine work of assessments proceeds at a simpler level.

Table 4. Terms Used for OCS-Related Operation Activities in the Selective Assessment Method

Operation Activity	Operation Activity
Chemical Broadcast	Pipe-Coating
Circulation of Cooling Water	Piped Gas Transmission
Circulation of Process Water	Piped Oil Transmission
Gas Liquefaction and Regasification	Road Traffic
Groundwater Withdrawal	Solid Waste Disposal
Maintenance Dredging	Steel Processing
Marine Oil Transport	Stormwater Conveyance
Marine Traffic	Wastewater Disposal
Oil and Gas Processing	Welding

2.2.4 Impacts

It is important to recognize that impacts are the elements that directly affect human needs and desires. Thus, a reduction in mallard populations is an impact because people desire to shoot and eat mallards. Similarly, coliform pollution of shellfish is an impact because people need to eat clean shellfish. But neither pesticide pollution of the water nor loss of submerged grass beds is an impact because they do not usually directly impact human needs and desires. Instead, they are ecological effects which lead to impacts but are not themselves impacts.

One often encounters lists of items called impacts that read like this: dredging, suspended solids, siltation, oxygen depletion, bottom disruption, loss of oysters, and boat channels. Little can be done to analyze such a list of "apples and oranges" until the items are related to recognized elements of the impact cycle. For example, these items can be related to the impact cycle as follows:

Item	Element
dredging	activity
suspended solids	effect
siltation	effect
oxygen depletion	effect
bottom disruption	disturbance
loss of oysters	impact
boat channels	subproject

With the items appropriately identified, analysis will show the cause and effect sequence as follows:

Element	Item
subproject	boat channel
activity	dredging
disturbance	bottom disruption
effects	suspended solids
	increase siltation
	oxygen depletion
impact	loss of oysters

In this example, the major activity causing problems is dredging a channel to a marina. To prevent the disturbance leading to loss of oysters by siltation, the proposed work might be modified in one of three ways: no dredging permitted, dredge only after oyster spawning is finished so that the settling of floating oyster larvae on firm underwater substrates will not be disturbed, or use a "turbidity screen" to confine the plume of suspended particles.

2.3 THE PROCESS OF IMPACT ASSESSMENT

An assessment system is outlined below which harmonizes with the system of information presented in this and other volumes of the "Environmental Planning for Offshore Oil and Gas" series. It is also compatible with the system of assessment that has been in use by the FWS for many years in reviewing permits under the FWS Coordination Act and for several years in reviewing EIS's under NEPA. Table 5 presents the bare framework

Table 5. A Framework for Ecological Impact Assessment

	Sequential Steps
Step 1.	Analyze Proposed Work Plan Review and analyze permit applications and accompanying information to determine the exact nature and the stages of work: o Identify subprojects (primary and secondary) and their relevant design features. o Identify activities and their relevant construction methods and operating characteristics.
Step 2.	Select Activities with Potential for Significant Disturbance Check the activities in Step 1 for probable generation of significant disturbance; select for analysis (in Step 3) those with apparent disturbance potential: o Screen identified activities for potential disturbance to fish and wildlife and habitats. o Select for analysis those with potential for significant disturbance.
Step 3.	Analyze Potential Disturbance Consider each activity selected for analysis by the following sequence: o Activity: Description and sources of disturbance. o Disturbances: Description and sources of adverse (or beneficial) effects.

(continued)

Table 5. Continued

	Sequential Steps
Step 3 continued.	o Effects and impacts: Description of effects sequence and probable impact of each disturbance.
	o Additive and cumulative effects: Description of probable exacerbated impacts.
Step 4.	Identify Beneficial Modifications to Work Plan
	For each activity verified as having a significant adverse impact potential (in Step 3), describe changes which might reduce impacts to acceptable levels by the following sequence (either design or performance specifications):
	o Design/layout changes.
	o Changes in construction or operation.
	o Mitigation opportunities (enhancement, restoration).
	o Substitute projects (location, alternative project or subproject).
Step 5.	Make Technical Recommendation
	In consideration of results of Steps 3 and 4, recommend acceptance, non-acceptance, or conditioned acceptance.
Step 6.	Make Final Recommendation
	After considering reactions from other agencies and individuals, as required, make final recommendations.

of the assessment system. It is devised more for typical onshore project review than for the specialized reviews involved with offshore leasing and recovery operations. (See Volume IV of this series for a discussion of FWS's role in OCS leasing.)

2.3.1 Analyze Proposed Work Plan (Step 1)

Whether it is a permit application or an EIS, the basic document along with its attachments must contain sufficient information for the assessor to determine the exact nature of the work, the stages by which it would be accomplished, and the specific activities that would be conducted. The activities are the key element in the impact cycle. They cause disturbances which trigger the sequence of ecological effects which lead to an impact. The activity is also the point of control for ecological protection measures and the point of opportunity for permit conditions and for mitigation recommendations.

In the process of analyzing the workplan for OCS-related development, the assessor first determines from the sponsor's proposal whether the project has more than one component. If so, the assessor then identifies each subproject and the activities involved in its implementation, setting the stage for the disturbance identification to follow.

2.3.2 Select Activities with Potential for Significant Disturbance (Step 2)

In this step, the assessor makes trial assumptions of disturbance impact,and tests these against his or her knowledge and experience, or that of colleagues or outside experts. The purpose is to winnow down the activities (or whole subprojects if possible) to those that have a reasonable probability of causing significant disturbance. Since those activities selected will receive detailed review in step 3, efficiency dictates that they be no more numerous than necessary.

For example, the assessor may be reviewing a permit for a pipecoating yard and find that a bulkhead subproject is involved. Further checking may show that the bulkhead as planned will preempt valuable wetlands through dredging activities in front of the bulkhead and filling activities behind the bulkhead but that other related activities, such as pile driving, have limited disturbance potential in this case. Therefore, under the bulkhead subproject in step 3, the assessor might select for detailed review as construction activities the dredging in front and the filling behind the bulkhead.

2.3.3 Analyze Potential Disturbance (Step 3)

The activities selected in step 2 are here subjected to detailed examination to determine probable effects and impacts. This analytical process is difficult to describe. In it, the assessor uses his own knowledge of the severity of effects resulting from particular disturbances. The assessor may also consult with others having special knowledge, or may refer to the literature. Often the findings of well-known experiments or general ecological theory can be applied successfully to the specific case.

Often, an experienced assessor can make reliable judgments of final impact simply by knowing the extent of the anticipated disturbance from identified activities. This is possible because experience shows that many disturbances have such predictable effects leading to such predictable impacts that these can be generalized from one case to another or from one documented case history to another.

Once the individual disturbance evaluations have been made and the full range of effects is outlined, the job remaining is to consider additive effects. This is easy enough if disturbances in two cases are the same and are therefore directly additive. For example, the effects of turbidity from hydraulic dredging of a channel may be added to those of dragline dredging of a boat basin, because the disturbance (release of suspended solids) is the same in both cases. But it is not so simple if the disturbances are different. For example, the eutrophication effects of channel dredging are difficult to add to those of sewage discharge during facility operation. No firm rules are available to guide this additive process; it must be worked out on the basis of experience.

There is another category of concerned called cumulative impacts, also known as incremental impacts or loss by attrition. The problem is widely recognized, but there are no accepted rules for solving it. The assessor's reaction most often will be simply to point out specifically those alterations which will add to the known accumulated alterations of the past. Usually the project sponsor has no better ground rules than the assessor for deciding "how much is too much" for an ecosystem, and will supply no information on the subject. No solution is offered here because the acceptable limits of cumulative impacts is more a policy matter than a technical one. It is expected, therefore, that the assessor will pass this problem along for resolution at steps 5 and 6 in most cases, unless policy on such matters has been decided in advance for the area and the type of activity in question.

The judgment of whether any impact is significant usually requires the assessor to look beyond the limits of the project area. A key question is, how large an area should be considered in relation to the effects of the project. It is usually necessary to set some boundaries for the area under consideration, particularly for large-scale projects with potentially serious adverse impacts. The ecological effects should then be determined in sufficient detail to make a thorough analysis for each of these: (1) the project area; (2) the immediately adjacent ecosystem; and (3) the wider area ecologically affected by the project for each of the following situations: (a) under optimal conditions (without any human interference); (b) as the areas presently exist, having been influenced by society; (c) as they will be affected by other activities occurring or expected to occur (cumulative impact); (d) as they will be affected by the project itself (e.g., by dredging, filling, or construction); (e) as they will be affected by each of the known alternatives to the project; (f) as they will be affected by combinations of secondary activities induced by the project or its alternatives.

While this depth of analysis may usually be required for large OCS-related projects, routine smaller permit cases may require much less complex assessment. However, the same concepts apply.

This is the stage for dispelling doubts about marginal cases. If an activity being tested in this review proves, under the assessor's analysis, not to have significant potential for impact, it is tentatively dismissed. On the other hand, if any activity is identified as having a potential for significant adverse impact, it is carried to step 4.

2.3.4 Identify Modifications to Work Plan (Step 4)

The assessor usually has the opportunity to suggest modifications to the proposed project. In fact, most permits reviewed in depth by the FWS are approved with conditions. To suggest modification often requires a higher degree of informed judgment than to forecast adverse effects.

The variety of possible modifications is summarized below in four general categories:

1. Design changes: This category includes all changes in design (including layout) of subprojects that reduce adverse effects.

2. Changes in construction or operation: This category includes all changes in construction and operations that may be suggested to ameliorate or reduce the severity of adverse effects.

3. Mitigation: This category includes any additional work recommended to reduce the damage caused or to restore ecosystems.

4. Substitute projects: This category includes suggestions for alternative projects to accomplish the human need as a substitute for proposed projects that are environmentally unsuitable for the location proposed.

Suggestions for modification must be tailored specifically to the circumstances of the project under review and may range from a small set-back (to preserve a fringing marsh) to a major rescheduling of dredging (to avoid the spawning season). Whether a change is practicable or not depends upon many factors, such as the planned sequence of events, the degree of commitment of the sponsor to the present configuration, the costs that would be incurred, and the timing of the modification in the overall construction sequence.

Project Location

By the time a permit application is filed, a site has usually been chosen for proposed development. Often the site has been purchased or optioned. As a result, the FWS staff rarely has an opportunity to discuss its selection with the project sponsor. In some major cases this may be unfortunate because site selection reduces future capability to avert adverse effects upon fish and wildlife and their habitats.

Project Design

While some aspects of design become fixed early in the design process, causing the sponsor to be reluctant to change,others remain adaptable after the permit application is filed. Consequently, assessors have more opportunity to suggest modifications of project design than modifications of project location.

Because waterfront development has high potential for disturbance, maximum care must be taken in its design. Solutions include provisions for: (1) maintaining the natural shoreline; (2) minimizing dredging; (3) arranging proper disposal of spoil; (4) avoiding wetlands; (5) reducing problems of runoff discharge through proper watershed management; and (6) provision of buffer strips.

Project Construction

Work on the land, particularly preparation and development of the site, can cause a number of serious effects on coastal waters. These can be ameliorated through: (1) minimizing the alteration of water systems; (2) preventing the erosion of soil; and (3) eliminating the discharge of toxic or deleterious substances. Immediate revegetation of disturbed areas can be accomplished to reduce erosion; excavation and filling of areas near wetlands can be done so that sediments do not degrade wetlands.

Project Operation and Maintenance

Latitude for modification of operations is normally limited only by inflexibilities of equipment and process set in the design stage. Therefore, it is important to consider operation-related disturbances in the assessment even though placement and construction are the major topics of the application, because permit review may be the last opportunity to incorporate basic changes to alleviate future adverse operational effects. (The major operational problems of many OCS projects will be in meeting pollutant discharge standards on waste disposal and runoff water required by Federal and state pollution controls.)

2.3.5 Make Preliminary Recommendation (Step 5)

At this stage, the question of scale becomes central. How much ecological alteration of any kind is acceptable and how much is not? The answer must ordinarily come from judgment, not rule. Therefore the assessor leans on experience and precedent in formulating his recommendation for action on the permit after considering probable disturbances and likely modifications. The judgment is based on available scientific evidence and knowledge of public needs, requirements, and desires as set forth in agency policy. Public interest balancing is usually beyond the scope of the assessor's job, but he should be aware that it lies ahead.

The preliminary recommendation of the reviewer may take one of four forms:

- o Acceptable
- o Acceptable with conditions
- o Unacceptable, with alternative suggested
- o Unacceptable, no alternative

Suggested conditions can take either of two forms: (1) design specifications, in which the assessor recommends a specific engineering solution (for example, a turbidity screen, or diaper, to prevent a fugitive dredge plume); or (2) performance specifications, in which the assessor recommends only the result he wants (for example, no release of dredge materials in open water).

2.3.6 Formulate Final Recommendation (Step 6)

In this stage, the assessor is reconsidering his recommendations in view of informal comments from colleagues, citizens, and other agencies, prior to the final FWS recommendation. In this stage a variety of policy matters or precedents may be considered. Because these judgments go beyond technical matters, they are not discussed in this report.

2.4 VITAL AREA PROTECTION

Certain components of the coastal ecosystem are recognized as ecologically vital and in need of protection. They are essential to the survival and well-being of certain species, to the functioning of the entire ecosystem, and thus to the maintenance of biological carrying capacity. These components serve one or more of three major functions--productivity, structure, and habitat. Vital productivity areas, such as salt marshes, supply nutrients to the system. Vital structural areas, such as sand dunes, physically bind the ecosystem and maintain its storm resistance capability. Vital habitat areas, such as shellfish beds, provide living space for particular species. Major vital coastal habitats are as follow:

Freshwater Wetlands	Includes all vegetated areas with saturated soils, permanently flooded or flooded long enough each year to support communities (two or more species) of water dependent plants. They include marshes, cypress domes, swamps,

Freshwater Wetlands, cont.	strands, bogs, sloughs, vegetated natural swales, and all other similar natural habitats. They take up, convert, store, and supply basic nutrient to the coastal ecosystem, often via transfer through the upper and lower saltwater wetlands. They act as buffer strips and retention areas, delaying the surge of stormwaters. They are intrinsically valuable, providing exceptional habitat and food for wildlife.
Dunes and Beach Ridges	Includes the frontal dune and all active secondary dunes; extending from the "toe" of the frontal dune or beach ridge (vegetation line) to the backside of the most inland active dune (active dunes visibly gain or lose sand; vegetated mostly with grasses rather than woody vegetation). They buffer the force of storm seas and provide capacity to store and yield sand to protect beaches and shorelands. They furnish turtle and bird nesting areas and valuable habitats for certain wildlife species.
Saltwater Wetlands	Includes all vegetated peripheral areas of the estuary, specifically, salt marshes and mangroves swamps. Recognized as areas subject to normal flooding by salt or brackish water and vegetated with salt tolerant plant communities dominated by certain grasses, rushes, or mangrove trees. The point above which there is no significant wetland marks the inner boundary of the coastal waters and approximates the 1 year storm mark--the point of the highest expected yearly storm surge. Upper wetlands lie between the 1 year mark and mean high water (occasionally flooded); lower wetlands lie between mean high and mean low waters; each is characterized by different plant species and has different ecological functions. <u>Upper wetlands</u> receive the flow of runoff waters, cleanse them of contaminants, intermittently export nutrients, provide habitat and open space/scenic benefits. <u>Lower wetlands</u> convert nutrients to organic detritus, an important element in the food chain of coastal ecosystems. Vegetation removes toxic materials, excess nutrients, and sediment. Vegetation also

Saltwater Wetlands, cont.	slows the surge of flood waters, breaks waves, and reduces flooding. Vegetation stabilizes shorelines, prevents erosion. Wetlands and tidal creeks provide nursery areas, other exceptional habitat, and open space/scenic benefits.
Submerged Grass Beds	Includes concentrated beds of submerged grass in shallow coastal waters. Where marshes are scarce, grass beds may play a dominant role by providing nursery areas, general habitat, primary productivity, and nutrient storage. They supply food to grazing animals and provide detrital nutrients. They add oxygen and stabilize bottom sediments.
Tideflats	Includes unvegetated areas that are alternately exposed and inundated by the tide. They may be mudflats, or sandflats, depending on the coarseness of the material of which they are made. They provide feeding areas for fishes (high tide) or shore and wading birds (low tide) and may produce a high yield of shellfish or baitworms. Tideflats are important energy storage elements for chemical nutrients.
Shellfish Beds	Includes all concentrations of molluscan shellfish on flats, banks, bars, or other bottoms. They provide an important economic resource and also provide a food source for certain fishes, birds, and mammals. Oyster beds particularly provide an exceptional and unique habitat for a diverse association of marine species.
Coral Reefs	Includes all coral reef structures. They provide habitat, structure and productivity wherever they are found. Fish, shellfish, and smaller marine organisms depend on the coral reef habitat for shelter and food, making it the center of many tropical biological communities.
Kelp Beds	Includes all concentrated beds of kelp in near-shore coastal waters. They break the force of the sea and provide a strip of quieter water between them and the shore. They provide food and favorable habitat for many fishes, as well as sheltered nursery areas for their young.

Convergence Areas	Includes areas of high concentration of species, (often seasonally) for particular critical functions such as: (1) breeding areas, where species concentrate for procreation; (2) nursery areas where the new young prosper because of food, predator protection, and other conditions; (3) feeding areas in marine basins where species concentrate; (4) migration pathways, where animals travel along narrow pathways to feeding, breeding or wintering areas; (5) wintering areas, where species concentrate in special habitats.

PART 3 - GENERATION OF DISTURBANCE BY OCS PROJECTS

This part reviews offshore and onshore projects related to OCS oil and gas recovery. The information is derived from Volume I of this series, "Recovery Technology," and from supplemental sources which are cited in the text. For convenience, the 15 projects of Volume I have been organized into 10 project groups as shown in Table 6.

Table 6. Projects in Volume I Organized into Project Groups for Purposes of this Volume

No.	Project Groups (this Volume)	Projects (from Volume I)
1.	Offshore Recovery and Transmission Systems	Geophysical Surveying Exploratory Drilling Production Drilling
2.	Offshore Oil and Gas Transmission Systems	Pipelines Offshore Mooring and Tanker Operations
3.	Onshore Terminals and Transmission Systems	Pipelines Oil Storage
4.	Service Bases and Repair Yards	Service Bases Marine Repair and Maintenance General Shore Support
5.	Platform Fabrication Yards	Platform Fabrication Yards
6.	Pipecoating Yards	Pipecoating Yards
7.	Oil Refineries	Refineries
8.	Petrochemical Industries	Petrochemical Industries
9.	Gas Processing Plants	Gas Processing
10.	Liquefied Natural Gas Systems	Liquefied Natural Gas Processing

Each of the ten project group sections is composed of three subsections:

- A Profile subsection provides basic information about the project (detailed descriptions of the various projects are given in Volume I of this series).
- A Siting Requirements subsection provides information on location of facilities.

- A Potential Sources of Disturbance subsection provides information on sources of ecological disturbance that affects fish and wildlife and their habitats. Individual subproject discussions acquaint the reader with project-specific features of the standard subprojects discussed in Part 4. The designation "SP-" plus a numeral in parentheses following the subproject title refers to the standard subprojects list given in Table 2.

3.1 OFFSHORE RECOVERY AND TRANSMISSION SYSTEMS

3.1.1 Profile

The process of recovering oil and gas from offshore fields can be broken into a number of fairly well-defined steps. Although these occur in sequence for any given tract over an entire field, several steps may proceed concurrently as new lease sales occur or sponsors carry out their exploration and development plans at different paces. This sec tion embraces the normal range of offshore development projects, i.e., surveying, drilling, and installation and operation of platforms. Pipelines, offshore moorings, and operation of tankers are addressed in Section 3.2.

Once a prospective field is identified and a lease sale announced, the recovery process begins with a massive data-gathering effort. Contractors gather stratigraphic and seismic data for each of the oil companies for interpretation by geophysicists and geologists. Based upon the interpreted data, oil companies bid for leases on available tracts. Successful bidders conduct exploratory drilling and, where successful, platforms are placed for development drilling and production. The products are delivered to shore through a pipeline laid on the seafloor or via tanker.

3.1.2 Site and Route Requirements

Site selection for an offshore platform is based upon subsea surface characteristics, oil or gas reservoir characteristics, ownership of adjacent tracts, and USGS lease stipulations. The most important factor is subsurface geology. Bottom conditions, including surface sediments and relief, limit feasible locations. From a construction standpoint, steep slopes and soft sediments are undesirable bottom conditions.

3.1.3 Potential Sources of Disturbance

The major ecological disturbances caused by offshore development are: (1) water pollution caused by discharges during drilling, (2) water pollution caused by discharges during pumping and preliminary processing of the oil stream on the platform, (3) pollution caused by oil spills from well blowouts, and (4) disruption of benthic organisms. Accidental releases of gas are considered to be ecologically inconsequential. Exploratory activities (seismic work and exploratory drilling) involve such minor disturbance to marine life, and to human uses of the ocean, that they are not discussed here. A past practice in seismic activities involved the use of dynamite and other explosives to generate the shock waves for geologic analysis. This practice has been abandoned by most progressive companies. If the practice is proposed, literature is available on the impacts of such activities.

Subproject: OCS Platforms and Offshore Structures (SP-18)

Disturbing Activities: Installation, operation

Although offshore platforms can have adverse physical effects on the seafloor life below, greater damage may be wrought by inadequate operational safeguards. Sizable oil spills may occur during drilling or production if formation pressure exceeds that which is anticipated.

Other possible disturbances that may occur include chronic discharges of oily formation water (brines) from platforms during production, disposal of drill cuttings and drilling mud during exploration and development (Table 7), and disposal of trash, garbage, and sewage. Properly controlled, the combined effect of disposing of these wastes is unlikely to be significant, unless the platform is located in an ecologically vital area. Improperly controlled, the effects can be significant; for example, the release of oil along with the discharge of "formation water" is in violation of EPA restrictions (maximum, 50 ppm oil) [2].

3.2 OFFSHORE OIL AND GAS TRANSMISSION SYSTEMS

3.2.1 Profile

This section discusses systems used for delivering offshore oil and gas to shore and for transferring and reshipping crude and processed hydrocarbons over or under the sea. The principal components of these delivery or transmission systems in current use are: (1) tankers or barges that may receive hydrocarbons directly from offshore wells, or, more likely, from onshore reshipment terminals; (2) offshore mooring and transfer stations for tanker loading from wells or for transfer of hydrocarbons at sea; and (3) pipelines used for direct transmission of hydrocarbons from offshore wells to onshore facilities.

Tanker operations can release oil in a number of other ways. Great tanker catastrophes, such as the spillage of 700,000 barrels of oil from the 118,000-ton tanker Torrey Canyon in 1967, are widely known. But the major source of oil pollution from tankers is intentional discharge, i.e., the pumping of oily ballast water and tank washings into the oceans. Modern oil tankers may range from 19,000-ton ships, used to transport oil short distances, to 500,000-ton supertankers. A 100,000-ton tanker is

Table 7. Possible Local Effects on Water Quality Caused by Discharges from One Platform in an OCS Lease Area (Source: Reference 2)

Activity	Maximum amounts	Open ocean impacts	Duration	Frequency	Effects
Discharge of formation water	.95 billion bbl.	local; platform locations	4th yr to life of field (30 yrs)	Throughout production phase	Local increase in salinity; concentrations of certain elements
Drill cuttings discharge	152,000 cu. yds	local; platform locations	Drilling phase 3-10 yrs	Continuous during drilling	Local increase in turbidity heavy metals in sediments potentially introduced to water
Drill mud discharge	124,000 bbl.	local; platform locations	Drilling phase 3-10 yrs	Continuous during drilling	Local increase in turbidity heavy metals in sediments potentially introduced to water

approximately the size of a large aircraft carrier. The draft of these tankers when loaded varies from 32 to 92 feet, depending on their size. Sixteen knots is the standard speed.

Offshore moorings are used in two different situations: (1) near an offshore platform to transfer oil from the well to tankers, or (2) near shore to transfer oil from tankers to an onshore terminal. The technology of offshore moorings is rapidly advancing. At present, the most favored type is a floating device secured by a number of anchors so that a tanker is moored at a single point and is free to rotate 360 degrees.

Pipelines have advantages over tanker transport. Bad weather conditions have little, if any, effect on a pipeline, but can disrupt tanker operations, forcing costly delays. The chances of a spill due to human error and mechanical failure are less for a pipeline because the oil flows constantly in a closed system, while tankers operate discontinuously, hooking up and then disengaging. Advanced monitoring techniques to detect leaks have been used more effectively for pipelines than for tanker loading systems.

3.2.2 Site Requirements

The optimum route for a pipeline is the shortest route between the field and the shore facility, but this is not always possible from an engineering standpoint. The depth and shape of the ocean bottom are the major factors in laying out the system because pipeline corridors must avoid deep trenches and rugged terrain. Bottom sediments and currents also affect the design. Because USGS may require that pipelines on bottoms shallower than 200 feet be buried, the routes usually will not cross hard bottoms, nor can pipelines make landfall at sea cliffs. Geologic hazards, such as active faults or areas of sediment slumping, can also cause detouring of the corridor route. The route should also avoid major interference with commercial fishing, shipping, and naval operations. The major requirements for anchored offshore tanker mooring buoys are: (1) suitable bottom for anchoring and (2) favorable logistics.

3.2.3 Potential Sources of Disturbance

Two ecological problem areas of great concern are benthic (bottom) habitat disruption and oil spills. Benthic habitat disruption occurs in the process of laying pipelines, particularly in the shallower coastal waters where the pipeline is laid under the bottom by a "bury barge" which both digs the trench and lays the pipe. Oil spills may occur anywhere along the transport route because of pipeline rupture, tanker accidents, and routine tanker operations such as discharge of bilge washings. Human error during transport and transfer operations appears to be a major cause of oil spills.

Great tanker spills, resulting from collisions or groundings, have aroused public sentiment against oil carriers. Most tanker accidents occur in heavily traveled or shoal water areas, which are usually near the environmentally sensitive coastline. Oil spills from pipeline breaks are sometimes caused by anchors snagging exposed pipelines. These events have been less publicized, possibly because most of the breaks (as well as nearly all of the drilling and production accidents) have occurred off remote, undeveloped shores of Louisiana. On the other hand, tanker incidents have often plagued heavily populated harbors and developed shorelines.

The possibility of large oil spills first arises during exploratory drilling. Oil and gas, held under high pressure in porous subsea rock layers, may be vented by a well placed drillhole. If not controlled, the well then would become a "gusher", once welcomed as a sign of success, but now carefully avoided, especially in offshore oil development. Complex blowout preventers incorporating many backup systems and steel well casings firmly cemented in place are now employed to reduce the likelihood of a blowout (USGS requires the use of such safety devices [3]. The probability of a blowout has also been reduced by improved drilling practices such as using heavier drilling mud, and by calculating risks of blowouts by conducting more detailed exploration of a field, using COST holes and modern seismic techniques. Nonetheless, since 1956 the USGS has recorded 48 blowouts in the Gulf of Mexico alone.

An additional risk of blowouts is incurred during the "workover" phase when wells are reentered to eliminate clogging or perhaps are deepened to bring deeper formation layers into production. The use of blowout prevention equipment during this phase of production is again an important safeguard. Careful monitoring of well pressure is especially important during workover when it may not be possible to use heavy drilling mud to control down-hole pressure sources.

Subproject: Marine Transportation Systems (SP-19)

Disturbing Activities: Oil transfer, oil transport

More than 70 percent of all oil discharged or spilled from tankers is during routine operations, particularly bilge washing [4]. A few tankers have separate ballast tank systems,but most of them load the empty oil tanks with seawater to maintain sea-worthiness on the return leg of the journey. Oily ballast water is discharged (which may have been partially treated) upon arrival. An additional source of pollution is spillage from tankers during transfer operations. Mechanical failure, faulty design, and human error account for most of these accidents.

Offshore tanker mooring buoys, usually single-point moorings (SPM), are either large buoys anchored to the sea bottom or towers fixed to the bottom. A tanker is moored to the SPM and loading hoses are connected. The mooring and hoses can rotate around the SPM to allow a tanker to head into prevailing winds or tides. With this flexible mooring system, a tanker can remain moored and continue loading in 15 to 20 foot waves [2]. The frequency of oil spills from SPM's and shoreside marine terminals is reported to be about the same [5]. In both, oil is transferred through flexible hoses or fixed couplings. Hoses wear out quickly in rough seas, and couplings break. The same likelihood for human and mechanical failures exists. Both harbors and SPM's average one oil spill for every 50 ship calls [5]. However, SPM's extend the range of tanker operations, increase the use of tanker volume, eliminate lightering, and minimize dredging requirements.

Subproject: Submerged Transmission Systems (SP-20)

Disturbing Activities: Pipeline installation; oil and gas transport

Construction disturbance associated with pipeline installation begins with trenching of bottom sediments by jet sleds during pipe burial. This causes an increase in turbidity and displaces benthic organisms or disrupts their habitat. Some bottom sediments are too hard to be jetted, so explosives must be used. Nearshore corridors are most likely to traverse environmentally sensitive areas, particularly in the estuaries behind barrier islands. The pipeline landfall is also an environmentally critical point. Special protective and restorative measures must be taken when pipelines cross beaches, wetlands, heavy surf zones, or sea cliffs.

Turbidity and its impacts on benthic organisms have been reported to occur 200 plus feet from the pipeline construction site. Shrimp have also been recorded to be attracted to the new bottom sediments after pipeline burial. If benthic organisms are displaced they will usually reestablish within 18 months after construction. The onshore and nearshore impacts of pipeline construction are the most damaging and lasting.

Currently, all the oil produced off California and 97 to 98 percent of Gulf of Mexico oil is piped ashore. Moreover, all present U.S. gas production is piped ashore because of the proximity to shore. Gasification plants have not been constructed in the U.S. because of the immediate access to market areas or economical quantities of gas are too scarce to justify construction. When small quantities of gas are available three options are available: (1) run the gas with the oil in a pipeline, (2) reinject the gas to maintain formation pressure and (3) flare the gas at the platform.

Because most of the known potentially hydrocarbon-bearing formations lie within 200 miles of shore and are in water of suitable depths, pipelines will probably continue as the preferred OCS transportation mode for the United States [5]. However, gasification plants may become economical in Alaska as large finds are occurring and a market is not immediately available. Table 8 shows that the expected number and total volumes of oil spills are greater for tankers than for pipelines, regardless of the size of the hydrocarbon find. At present, therefore, pipelines also appear to be environmentally safer than tankers.

Table 8. Potential Oil Spill During the Life of an Oil Field (Source: Reference 6)

Size of Find	Number of Spills	Barrels Spilled
Small Find		
Platform	0.28	7,200
Pipeline	0.31	13,900
Tanker	0.41	19,900
Medium Find		
Platform	1.3	33,300
Pipeline	1.4	62,900
Tanker	1.9	92,400
Large Find		
Platform	4.7	120,500
Pipeline	5.2	233,300
Tanker	6.9	335,700

of the hydrocarbon find. At present, therefore, pipelines also appear to be environmentally safer than tankers.

3.3 ONSHORE TERMINALS AND TRANSMISSION SYSTEMS

3.3.1 Profile

An onshore marine terminal for loading or offloading tankers may serve as one or more of the following: (1) a receiving terminal for very large crude carriers (VLCC) delivering oil for nearby processing facilities; (2) a transshipment terminal for loading crude oil produced offshore and brought by pipeline to an onshore storage facility; (3) an LNG receiving terminal (discussed in Section 3.10); and (4) a product terminal for offloading and storing refined products brought by tankers for subsequent pipeline, truck or rail delivery to the market.

Such a marine terminal will typically have the following major components: a berthing system for ships, loading and/or unloading equipment, storage tanks with dikes, pumping station, fire protection facilities, and, usually, direct connection to an onshore pipeline. The decision whether to build a terminal directly on the waterfront (shoreside) terminal) or out in the nearshore waters (nearshore terminal) is based on consideration of the water depths available at each site, the nature of the shore itself (sand beach, rocky cliff, coastal plain, etc.), the draft of the largest expected vessel, and the expense of channel dredging (initial and maintenance). (Offshore oil and gas transfer systems (including deep ports) are discussed in relation to offshore moorings in Section 3.2.)

Natural gas is piped directly from offshore fields to processing plants. Some processing (such as separation) may take place at a marine terminal/storage tank complex if the output from offshore production includes both oil and gas and is piped to shore in the same line. The oil will be sent to a storage tank and the gas directly to a final processing plant.

An oil storage tank complex is normally required in conjunction with a marine terminal site for crude oil, because tankers move oil in batches, while production and processing units operate more or less continuously. Oil production close to processing facilities allows direct piping to refineries and will require substantially less storage capacity than will production in more remote areas which is likely to require tanker transport to refineries.

Most "shoreside" terminals are built inside a harbor. They may have one or more piers running either parallel or perpendicular to the waterfront. A variant, the "nearshore terminal", consists of the same major components as shoreside terminals but is built far enough offshore to be in the required depth of water for the ships it is to serve.

The decision to build a marine terminal on the coast adjacent to an OCS field is made at the same time that production and transportation strategies are determined. A new terminal might be developed in the area adjacent to a proven OCS field if pipelines are uneconomical and refineries are distant. In such cases, small tankers might bring in crude oil from production platforms for transshipment by larger tankers. A marine terminal could also be developed if a refinery exists or is planned in the adjacent region and some or all of the offshore production is expected to be refined there. On the other hand, a likely case for marine terminal development is a highly productive field relatively close to shore (less than 150 miles), wherein the terminal would receive crude oil by pipeline for loading into large tankers [3].

3.3.2 Site Requirements

Marine terminals, where possible, will be located in existing harbors with pipeline connections to storage tanks. If no appropriate harbor is available, a terminal may be located in the nearest waters that offer shelter from adverse weather conditions. The storage tank area does not need to be on the waterfront; for example, storage tank farms are sited three miles inland from two marine terminals located in the United Kingdom [7]. However, waterfront area may be required for a pumping station.

An oil storage area with a capacity of from one million to three and one-half million barrels may require roughly 20 to 60 acres. Some additional land is needed for office and maintenance buildings, the pipeline corridor, or a pumping station. More space may be necessary for processing units if partial processing (oil-water-gas separation) does not occur at the offshore field or if a sulfur treatment facility for sour crude is required [7].

The size of a terminal depends on the rate of flow of oil from offshore, the number of berths, the size of the tankers, and the frequency of arrival. Extra storage is needed to provide for the irregularity of tanker arrival. For example, a 250,000 B/D nearshore terminal with storage capacity of one million barrels (in four 250,000 BBL tanks) would require about 30 acres, assuming no on-site processing is performed [7]. The marine terminal site must be level, normally with a surface grade of less than three percent. Because of the weight of large capacity storage tanks, good load-bearing soils are required, as well as geologically stable ground. Storage tank foundations require a bearing strength in excess of 7,000 pounds per square foot [7]. Pile foundations may be required where soils cannot meet bearing capacity requirements.

A new site for the berthing operations of a marine terminal will necessarily be adjacent to a suitable navigation channel, or located nearshore in deep water. A turning basin area big enough for the largest expected vessels must be available or be created by dredging. A typical layout for a double berth sea island terminal is shown in Figure 3.

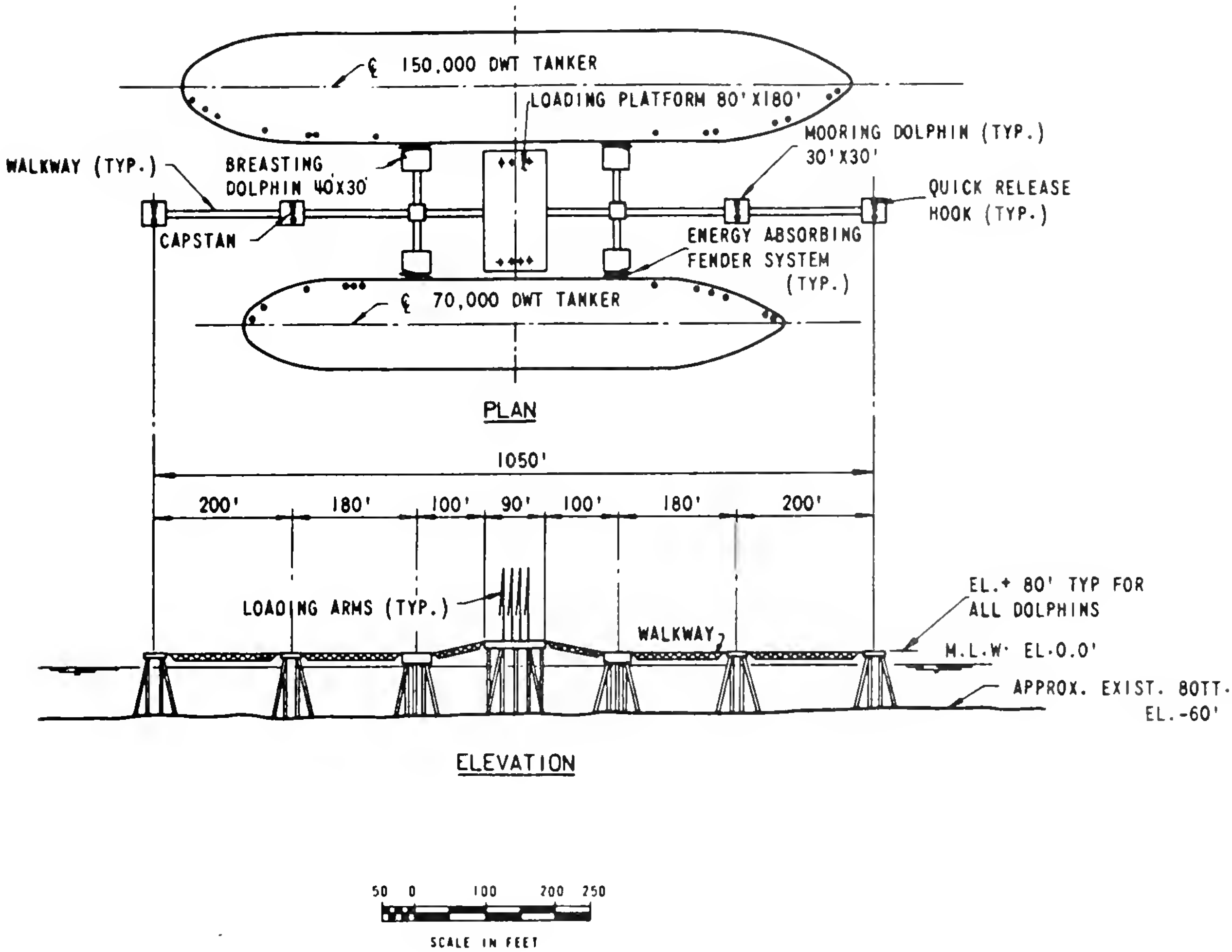
Water supply is important if processing is to take place at the terminal. Electric power requirements for a typical terminal are estimated at about 8 million kwh/year at the terminal pier. Fuel storage will be required for service vessels and equipment, including tug boats, launches, pilot boats, and for diesel generators.

The most important factor in construction of an onshore pipeline system is the availability of a suitable overland route (pipeline corridor). Capital and operating costs are held to a minimum, as far as possible, by selecting the shortest route. Corridor widths vary between about 50 feet and 150 feet, depending on several factors, including the expectation that further parallel lines may be added to increase the capacity of the system. The number of pumping stations depends on distance, and the planned initial rate of flow (which may be considerably less than capacity). Additional stations may be added as the amount of oil or gas to be transmitted increases. The use of existing rights-of-way, such as power line corridors, can lower initial costs and reduce environmental disturbances.

3.3.3 Potential Sources of Disturbance

New marine terminals may disturb fish and wildlife and their habitats, especially when the terminals are located outside of existing harbors.

Figure 3. Typical layout for mid-depth sea island (nearshore) terminal(Source: Reference 8).



Major impact-generating activities include: onshore pipeline installation, channel dredging, pier and dock construction, oil and gas transfer operations, development of a water supply, and disposal of wastewater. Other important potential sources of disturbance and adverse effects on fish and wildlife are site clearing and grading activities, new highways, rail connections, and solid waste disposal.

The evaporative losses of hydrocarbons from storage tanks and the release of vaporized hydrocarbons into the air at transfer points are problems of relatively minor fish and wildlife concern, but may be of significant concern to human health unless storage tanks are equipped with efficient vapor recovery systems.

Subproject: Navigational Improvement (SP-1)

Disturbing Activities: Dredging; spoil deposit

Dredging may be required in existing harbors to meet the water depth requirements of the expected marine terminal vessel traffic. The size of the vessels will vary depending on the projected volume of oil or gas to be handled, and the available depth of water. Vessels of 120,000 and 250,000 dead weight tons (DWT) typically require water depths of 60 feet and 80 feet, respectively [9]. A 500,000 DWT supertanker would need 105 feet of water (note that these depths are minimums). During the construction phases of the terminal much barge traffic can be expected in order to deliver steel sheets for storage tank fabrication, and other materials.

A new shoreside marine terminal system may require extensive channel, berthing, and turning basin dredging, as well as maintenance dredging, to the depth necessary to accommodate the vessels. Therefore, nearshore terminals are often preferred, since they reduce dredging requirements and subsequent alterations to shoreline systems.

A nearshore terminal often is located in relatively deep water. When such a pier is located in an area sheltered from the prevailing wind, waves, and currents, and in sufficiently deep water, navigational dredging requirements may be minimal, or even unnecessary. Furthermore, this alternative greatly reduces the need for costly, environmentally harmful maintenance dredging necessary for shoreside marine terminals located in existing harbors.

Subproject: Piers (SP-2)

Disturbing Activity: Installation

Shore terminals are of conventional design. Nearshore terminals are connected to shore by a causeway, trestle, or submarine pipeline. Tanker characteristics such as length or maneuvering capabilities determine terminal dimensions. The components of the terminal may include: a loading platform, breasting dolphins, mooring dolphins, loading arms, a walkway, and a fire protection system.

Breasting and mooring dolphins are normally pile supported structures with concrete decks. Mooring dolphins, designed to hold a ship's lines securely, may range from 30 by 30 feet to 70 by 70 feet [9]. Breasting dolphins also are equipped with mooring lines and typically measure 40 by 40 feet (see Figure 3).

Subproject: Site Preparation (SP-5)

Disturbing Activity: Clearing, grading, paving

Onshore pumping, storage and, if applicable, partial processing facilities, can be located either at a waterfront site or several miles inland. Development impacts will depend on site location, size of facilities, and site characteristics. A typical site for a storage tank farm will be entirely cleared, graded and leveled with specific areas worked for retention dikes, access roads and parking area. During the construction phase, storm water runoff may have significant environmental effects since it may contain contaminants (including metals from the welding, riveting and other metal fabrication required). Extensive earthwork construction may take place to provide dikes around the storage tanks to protect against spills. Each tank is individually surrounded with a dike of sufficient size to hold all liquids within it. Then the whole tank farm complex is surrounded by another dike to contain fluids if spilled. Large volumes of dredged or trucked fill material may be required to construct the dikes, to fill low spots or for general filling to raise the land above the 100-year flood level. Buffer areas for visual, noise, and runoff filtration purposes are normally used along the perimeter of the work areas and especially along water courses to protect ecologically vital areas.

Subproject: Overland Transmission Systems (SP-11)

Disturbing Activity: Line construction

A new marine terminal requires the construction of an onshore pipeline to link the loading/unloading facilities with the storage tanks. If it is a receiving terminal, an onshore pipeline is required to link the terminal with a processing plant, which normally is located within 50 miles. (Offshore pipelines are discussed in Section 3.2.)

Onshore pipeline systems usually are the most efficient, economical and safe method of transporting oil and gas inland from the coast. All pipeline systems require an initial pressure source and often intermediate pumping stations along the line. Whether intermediate pumping stations are needed is determined by the length of pipe, the diameter of pipe, the quality and type of fluid or gas being transported, and physical characteristics of the pipeline route (such as hills). Onshore pipeline installation is similar in many respects to installation of a sewer line or water main.

A pipeline corridor from the landfall to the storage and pumping facility and then perhaps to a distant processing facility can cause significant disturbance if routed through endangered species habitats or other vital areas. Pipeline installation activities--such as trenching, disposal of excavated material and backfilling--may have to conform to strict environmental standards, especially when crossing wetlands and water courses, to minimize disturbances to fish and wildlife and their habitats.

Subproject: Stormwater Systems (SP-12)

Disturbing Activity: Paving, stormwater conveyance

Leaks from tanks, valves, or pipelines in the storage tank area, if they occur, may contaminate storm water confined in tank diked areas. Normally the dikes built around the tanks to retain the liquid in case of accidental rupture are used to collect runoff water [7]. This stormwater system is separate from the stormwater system of the entire complex. The potentially contaminated water from the dike areas is placed in the waste treatment system, cleaned of oil with the API oil skimmer, aerated, treated and discharged. Runoff areas outside the dikes may require retention or settling ponds to collect and store the water before it is released but generally does not receive the extensive treatment offered for areas which come in direct contact with hydrocarbons.

Subproject: Solid Waste Disposal (SP-13)

Disturbing Activity: Solid waste disposal

The major sources of solid waste problems from a marine terminal system are storage tank and pipeline sludges. Periodically, sediment sludges which have built up in pipelines and tank bottoms are removed to containment facilities to prevent infiltration of toxic compounds into adjacent soils, ground or surface waters. Oil brine separator sludges also contain toxic compounds, including ammonio, sulfur, and ferric chloride, that require special storage and treatment. In the past, solid wastes were weathered, then buried in designated sludge pits. In some states, licensed contractors remove and dispose of the wastes, using state-approved methods.

Subproject: Industrial Wastewater Systems (SP-14)

Disturbing Activity: Wastewater disposal

Tanker bilge and ballast waters are the major sources of wastewater at a marine terminal. Other wastewater sources include domestic sewage cooling water, and stormwater runoff (and when applicable, process water). Bilge water accumulation rate for a 20,000 dead-weight ton tanker has been calculated at 80 gallons per minute, or about 115,000 gallons per 24 hours of operation [7]. Bilge water accumulated by tankers, tug boats and other service boats at a marine terminal is contaminated by fuel and oil leakage, and by metallic compounds from the machinery. The bilge water requires collection and treatment before it is discharged to receiving waters.

Marine terminals usually have a wastewater facility to separate and treat contaminated ballast water. Oil vessels require tank cleaning and deballasting whenever new cargo is to be loaded which will not tolerate residues from a previous cargo. It is estimated that 0.2 to 0.4 percent of an oil shipment will adhere to the storage tank walls [7]. Heated sea water is used to clean the cargo tanks. Ballast water effluent limitations are imposed by EPA (Table 9). The average tanker

Table 9. Effluent Limitations for Ballast Water in Pounds/Million Gallons of Flow (Using Best Available Technology Economically Applied) (Source: Reference 10)

Characteristics	Maximum for Any One Day:	Average Daily Values for 30 Consecutive Days Shall Not Exceed:
Biological Oxygen Demand (5 day Test)	0.088	0.071
Total suspended solids	0.084	0.071
Chemical Oxygen Demand	0.32	0.26
Oil and Grease	0.018	0.014

takes on about 40 percent of its capacity in ballast water. Thus, a 20,000 DWT tanker with a capacity of 140,000 barrels takes on about 56,000 barrels of ballast, which then is contaminated with about 280 to 560 barrels of the original tanker cargo [7].

Subproject: Marine Transport of Oil (SP-19)

Disturbing Activity: Marine oil transport

Both spills and leaks may occur during oil and gas transfer between vessels and storage tanks at a marine terminal. Although spills are usually due to human error, they may also result from equipment and structural failures in such components as manifolds, pumps, and valves. Other potential points of structural and equipment failures include: storage tank rupture or leak, hose rupture, and line or pipe leak.

Human error problems include: tank overflow, improper hose connection, and improper valve handling [11]. Protection structures for the storage tanks and pipelines, such as dikes and berms, are required to minimize the effects of spills. Gutters and collection basins on the loading pier can prevent leakage into the marine waters. Fire and explosion are also major potential hazards at the transfer terminal and storage tank farm.

3.4 SERVICE BASES AND REPAIR YARDS

3.4.1 Profile

Supply and support of offshore oil and gas exploration and development activities demands a complex array of onshore facilities. Onshore service bases which provide the necessary services and supplies for offshore operations are central to the OCS activity. Marine repair and maintenance yards also play a key support role.

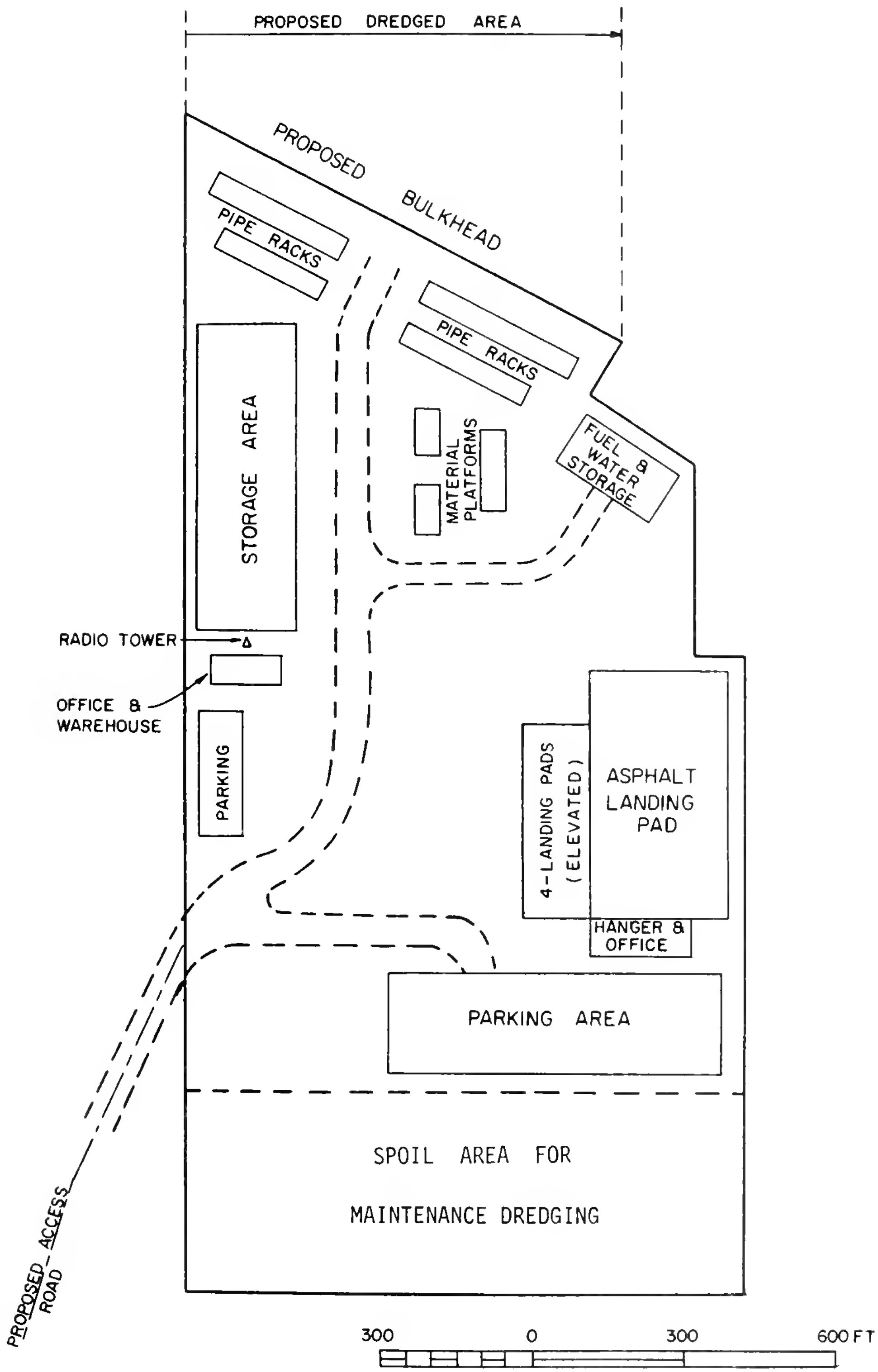
The ultimate extent of expansion or need for new construction at shipyards, harbors and other marine industrial areas depends upon the demands of offshore oil and gas recovery programs. Some of the factors that may influence the petroleum companies and support industries' onshore development options are the degree of success of drilling ventures, the capacity of existing facilities to meet new demands, the proximity of existing services and firms to offshore fields, the local area zoning and environmental controls, and community attitudes.

Service bases and repair yards are smaller than other onshore facilities. However, they have a potential for creating adverse effects on fish and wildlife and their habitats that is related to the size, scale, location, and activity level of service bases and repair yards, as explained in the following:

The temporary service base: This facility, used during the exploratory phase of offshore activities is the staging area established by an oil company or independent service contractor for shipping equipment, supplies, and personnel to offshore sites. The base may include berths for supply and crew boats, dock space for loading and unloading supplies, warehousing, open storage areas, buildings to house supervisory and communications personnel, and a helipad. The size of the base and level of vessel activity depend on the number and kinds of vessels and exploratory drilling rigs being served. The bases are relatively small, requiring limited acreage generally leased for a short term. Often public port facilities are used. Where no suitable buildings are available, one or more house trailers may be used.

The permanent service base: This facility provides essentially the same logistical support and services during the development and production phases as the temporary base does during the exploratory phase. But because as many as 50 wells can be drilled from one platform and additional platforms generally follow, the size and intensity of required support and services increase dramatically during development (Figure 4).

Figure 4. Typical service base layout (Source: Modified from Reference 12).



Marine repair and maintenance yard: These yards are operated by the firms which provide repair services for vessels and equipment used in OCS oil and gas development. Services required vary widely, but are likely to include structural, electronic, and mechanical repairs for tugs and for larger drillships, semisubmersible rigs, pipeline lay and jet barges, and pipe supply barges. Repairs to a wide variety of equipment may be included. Efficient service and highly skilled labor are the primary requirements for repair and maintenance work. Skilled workers may include certified welders, shipfitters, electricians, mechanics, machinists, riggers, carpenters, pipefitters, sandblasters, and painters. For underwater work either nearshore or offshore, skilled divers are required. Around-the-clock service is required during peak OCS activity.

3.4.2 Site Requirements

Service bases and marine repair and maintenance components most often are located at existing developed harbors. Proximity to the offshore field is a major criterion in a company's search for suitable harbor space. Service bases require year-round ocean access, wharf frontage, an adequate turning area, navigable channels, and uncongested inner harbors. Existing ports are not always able to readily accommodate service facilities--international shipping harbors may be geared to special cargo or passenger operations, and pleasure boat harbors are generally unable to provide ancillary services. The best option may be the deep sea commercial fishing port which has facilities for handling ships of comparable size and characteristics. Availability of water, electricity, and solid and liquid waste disposal services also are important considerations. In some cases, the location of bases established during exploration may prove convenient for the development phase and a larger area may be purchased or leased for a longer term. However, if the field is distant from the temporary base a more convenient site may be developed [7].

A temporary service base may require about 5 acres per drilling rig. Of the 5 acres, approximately one and one-half acres per drilling rig is used for open storage and warehousing, one-half acre per rig for operations and administrative offices, and one acre per rig for a helipad [7]. Certain economies of scale result when more than one or two rigs are being serviced. Temporary base siting decisions normally are made after a lease sale, although land options may be purchased earlier. If a permanent base exists within 100 miles of the leased tracts, a temporary base is unlikely. If the lease area is remote, temporary bases may be established before the sale. Because of the high cost of transporting men and materials, companies seek vacant land which can be leased on a short-term basis (one year or less) in those ports closest to offshore activity.

A permanent service base requires a 25- to 50-acre site in an all-weather harbor. Most space is used for warehouses and open storage. About one-quarter acre per platform is required for office, communications and parking space, and an acre per helicopter. Accessibility to road, rail, and air transport is necessary for fast delivery of supplies and parts. Land must be level, with a soil base capable of supporting heavy loads of pipe, storage tanks, and other materials and equipment.

Marine repair and maintenance yards may be part of either a new overall service base or existing industrial marine service areas. Thus, siting requirements of general application are not as easily stated as for other onshore facilities related to offshore oil and gas development.

3.4.3 Potential Sources of Disturbance

These facilities occupy moderate size tracts of waterfront land, usually in existing developed harbors where site development and road access systems may involve activities that have adverse effects. Also, the use of a waterfront site for a service base or marine repair and maintenance yard may involve alteration of the bay bottom and immediate shoreline.

The potential for small spills of hazardous substances is related to the level of activity in handling supplies and products, and transferring fuels. Storm wastewater systems may require extensive reconditioning of polluted stormwater before release to coastal waters. Where hazardous products are stored, diked drainage may be needed to collect runoff for treatment and disposal.

When fuel is stored on the base, good practice dictates that the tanks be located away from other components and be surrounded by berms or dikes to contain leaks or spills. Normally, one-quarter to one-half acre of land per offshore platform is required for fuel storage [7].

In most cases the base can rely on the local municipality for electricity, sewage treatment, solid waste disposal, and water. These needs are not exceptional. However, reasonably large quantities of fresh water are needed offshore: for example, during exploratory drilling about 5 million gallons per rig is brought from shore annually, and during development drilling the figure rises to 8 million gallons [7].

Subproject: Navigational Improvement (SP-1)

Disturbing Activities: Dredging, spoil deposits

Channels, berths and turning basins at service bases may have to be dredged to provide adequate navigational access for boats 200 feet or longer, including workboats, crewboats, tugs, and drilling rigs. The minimum channel and berthing depth is 15 to 20 feet. Supply boats equipped with bow thrusters (propellers set in transverse tunnels in the hull near the bow to aid in maneuvering) reportedly cause scouring and silting of the harbor bottom, and so necessitate redredging within a few years after initial construction. Such was the case at Aberdeen Harbor, Scotland []3]. Service bases and repair yards often are located in developed harbors which are typified by the accumulation of contaminated bottom sediments. Because heavy metals, hydrocarbons and other toxic compounds may be prevalent in the sediments, dredging existing harbors to improve navigation for OCS craft may require special techniques to reduce the resuspension of pollutants, as well as elaborate precautions in spoil containment and disposal.

Subproject: Bulkheads (SP-3)

Disturbing Activity: Bulkhead design

Where no existing harbor space is available for temporary and permanent service bases, new bulkheaded dock frontage for boat loading and unloading may be required. To service each drilling rig, two or three workboats and one crewboat may be needed, and for each drilling platform, four workboats and one crewboat may be required. During the long production period, one workboat usually will service two platforms. No crewboats are needed because the smaller crew can be transported by helicopter and workboats. For each offshore rig (temporary base) or offshore platform (permanent base) serviced an estimated 200 feet of waterfront is required [12].

Subproject: Site Preparation (SP-5)

Disturbing Activity: Site clearing and grading (design and construction)

Activities to develop a site for a service base repair yard complex vary considerably in their potential to affect fish and wildlife. The use of existing harbors or other marine industrial areas may require few or no site alterations. At new waterfront sites, complete clearing, grading, and paving of the work, storage, and parking areas usually occurs. Vegetated buffer areas are created along the perimeter of the work areas to screen visual and noise disturbances and to filter runoff.

Subproject: Site Development (SP-6)

Disturbing Activity: Line construction, fill removal and deposition

The working and storage areas would be leveled to maximum slopes of three percent. The majority of the area would be graded and much of it blacktopped. Plans for stormwater collection and treatment system, utility lines and other underground facilities must be included in the site development plan.

Shoreline alteration may be proposed for a new site, including filling of low areas, general filling to raise the land above flood hazard levels, and bulkheading and backfilling. Therefore, during site development large volumes of fill materials may be dredged or trucked in and the wetlands and littoral zones may be obliterated by bulkheads.

Subproject: Roadways and Bridges (SP-8)

Disturbing Activity: Roadway design

Large quantities of materials are handled by a service base to support exploratory and development drilling, production, and workover. Roadway and railroad access are essential siting considerations. Repair yards also may generate extensive shipments. The large volume of supply traffic and the use of heavyweight trucks may require new access roads, upgrading of old roads or a new rail link. Table 10 lists the quantities of materials handled by a service base to supply an offshore rig that drills four 15,000-foot wells per year.

Table 10. Estimated Quantities of Materials Needed for a Rig that Drills Four, 15,000-foot Wells per Year (Source: Reference 1)

Item	Quantity per Rig Year
Mud	2,568 tons
Cement	1,260 tons
Fresh water	5,200,000 gallons
Drill pipe, casing and tubing	1,820 tons
Fuel for drilling	13,272 barrels

3.5 PLATFORM FABRICATION YARDS

3.5.1 Profile

Offshore platforms that support oil and gas drilling and production operations may be constructed of either steel or concrete. Steel platforms are discussed in this section because they are the only type currently constructed and in use on the United States OCS. Some of the larger platforms being installed today in deep waters use 20,000 to 50,000 tons of steel (the Eiffel Tower is 7,000 tons of steel). The manufacture of these immense structures is done in specialized land-based facilities known as platform fabrication yards.

Platform fabrication yards are large, active industrial sites, which require heavy duty equipment and machinery, large quantities of steel pipe and tubing, and a substantial start-up investment ($30 to $60 million). The largest may employ more than 2,000 workers when operating at peak capacity [14]. Platform yards assemble rather than manufacture products, and their potential for continuous and harmful industrial pollution is minimal. There are now four major yards in the United States; expectations are that not more than two additional major yards will be built to meet the demand from all future OCS activities.

A single yard may simultaneously construct several jackets (platform frameworks) and smaller platform components and operate its own pipe mill. The deck and smaller platform components are built either at the platform fabrication yard or at a marine construction yard that can provide the special expertise and facility requirements. A fabrication yard becomes the nucleus of many ancillary businesses, such as welding supply shops, marine towing services, marine repair companies and heavy equipment sales. It might also incorporate within its boundaries a separate operation such as storage tank construction.

A steel platform fabrication yard usually occupies several hundred acres of cleared, level land adjacent to a navigable waterway that has direct access to the ocean. The typical yard has a great amount of open storage and work area interspersed with various sheds and buildings. The major work space is a jacket fabrication area. The yard may also have a pipe fabrication rack, a pipe-rolling mill, and other supplementary facilities, such as a plate and pipe shop, painting and sandblasting shops, an electrical shop, and warehouses. If the yard also produces the deck units for its platforms, it will have a deck and modular assembly building. A dry dock (graving dock) is also a possibility if very large platforms are to be constructed.

3.5.2 Site Requirements

Siting requirements of major concern in planning a platform fabrication yard are the availability of a large level tract of waterfront land, convenient navigational access, and the availability of an abundant supply of fresh water. Other important requirements include adequate roadway access systems, proximity to leased offshore areas, an ample supply of electric power, necessary basic service facilities, and adequate community facilities for the large labor force.

It is likely that locations for new platform fabrication yards will be sought in relatively rural or undeveloped waterfront areas. Generally, existing major ports and marine shipyard areas cannot readily accommodate new platform fabrication facilities because of their need for large tracts of land and clear navigational access to the open ocean. The large initial investment required for a new yard, and the fact that existing yards can supply distant fields make it unlikely that new yards will be located in the United States in addition to the two planned by Brown and Root, Inc., at Cape Charles, Virginia, and Astoria, Oregon. However, additional "specialty" or "satellite" yards may be built near offshore fields to produce a variety of individual platform components.

The sizes of platform fabrication yards vary depending on production demand and range of products; a new site may occupy between 200 and 1,000 acres of coastal land [15]. A land surface grade of less than three percent is normally desired. At a steel platform yard it is estimated that 50 to 60 percent of the area will be used for fabrication and about 40 percent for storage [16].

Operations at a steel platform fabrication yard require moderately large supplies of fresh water for such activities as cooling of steel, washing of steel after sand blasting, and, where incorporated, pipe rolling. Electric power requirements may be moderate unless the yard has its own pipe mill. The numerous welding units may be largely driven by individual diesel-powered generators.

A new site for a steel platform fabrication yard will necessarily be adjacent to a navigation channel large and deep enough for the barges used to transport the jackets to offshore sites and for the largest ships that may bring steel and other materials to the yard. Yards are generally located seaward of low bridges and other navigational obstructions.

Convenient transport of materials, personnel, fuels, equipment, and supplies to the platform yard requires adequate road and rail systems. Thus, land transportation systems are another important siting consideration.

3.5.3 Potential Sources of Disturbance

Platform fabrication yards have a comparatively high potential for adverse effects. They occupy large tracts of waterfront land, receive large quantities of heavy industrial materials, and require a larger labor force than other onshore OCS-related facilities. Dredging, bulkheading, road construction or improvement, site clearing and grading, excavation of an enclosed graving dock, and fresh water withdrawal are characteristic activities that may cause adverse effects on fish and wildlife and their habitats.

A coastal tract of the dimensions of a platform yard can include significant components of terrestrial and avian wildlife habitats, which would be largely eliminated or degraded during site clearing and development. In addition, other areas may be used to obtain fill, with similar damaging effects on wildlife habitats and on aquatic resources.

Subproject: Navigational Improvement (SP-1)

Disturbing Activities: Dredging, spoil deposition

Dredging may be required to provide accessible channels, berths, and turning basins for supply ships, barge traffic, and platform transport barges. The largest platform barges have a beam of 60 feet or more, and a draft up to 15 feet; therefore, the desired channel width is usually about 300 feet (five times the beam), and depth about 18 to 20 feet below mean low water. However, supply vessels might require considerably deeper channels and turning basins, perhaps to 30 feet below mean low water. Much barge and ship traffic can be expected, since an average of 9,000 tons of steel per platform is required for construction [17] and the amount can go to 50,000 tons for the very largest ones [18].

The extent of dredging and spoil disposal to be expected can be predicted with accuracy only when the specific requirements for marine transport are available. At the rural or semi-rural locations expected for platform yards, the likelihood of spoil disposal on land is high because land is not as scarce or expensive as in developed waterfront centers. If the navigation channel to deep water exceeds one mile, then open bay disposal might be anticipated. If the dredged material is coarse, it can be used for on-site fill. Spoil from maintenance dredging will contain concentrations of organic material and possibly heavy metals, oils and other pollutants. These should be confined in diked upland disposal areas.

Subproject: Bulkheads (SP-3)

Disturbing Activity: Bulkhead design

Ship loading and unloading facilities, a key requirement in platform yards, would usually be provided by bulkheaded shore frontage. Conventional piers would not be feasible for launching heavy steel platforms. Since bulkheaded frontage would be available, it might also be expected that supply ships would unload there.

A new platform yard may occupy from several hundred to many thousands of feet of waterfront. Many factors are involved in determining the amount of bulkheading required. Where the jackets are launched directly into an adjacent water body,the shorefront may be bulkheaded for much of its length. Other factors affecting the decision include the configuration of the yard, the number of jackets expected to be under construction at any one time, and the dimensions of the jackets. At some yards, the jackets under construction would be lined up in a single row perpendicular to the bulkhead. At others, the jackets would be arranged parallel in columns perpendicular to the bulkhead. Additional bulkheaded shore frontage is required to handle the unloading of supply ships bringing steel or other materials to the yard without interfering with jacket assembly.

Subproject: Site Preparation (SP-5)

Disturbing Activity: Clearing, grading

The usual method of site preparation for a platform fabrication yard would involve complete clearing and grading of the work, storage and building areas. The working areas would be leveled to a maximum gradient of three percent. Much of the site is left bare or partially surfaced. A buffer strip to reduce noise, improve appearance and filter runoff is determined by the amount of available land and other factors.

Subproject: Site Development (SP-6)

Disturbing Activity: Fill removal, deposition

If there is to be extensive shoreline bulkheading, or if spot filling of low areas or general filling is needed to raise the land above flood hazard levels, a considerable amount of backfill may be needed from off-site locations. Therefore, large volumes of fill material may be required (unless graving dock excavation provides an excess of high quality fill material) posing the threat of bay dredging. On-site roads and building foundations occupy small areas and are a minor concern in assessing a yard's effects on fish and wildlife following the initial loss of habitat resulting from yard construction.

Subproject: Artificial Waterways (SP-7)

Disturbing Activity: Excavation

A subject of major concern is the possibility of excavation of a graving dock within the site for fabrication of large steel platforms. The graving dock could be up to 2,000 feet long, 600 feet wide, and 40 feet deep [19] and produce more than 2 million cubic yards of excavated material. The graving dock would be furnished with lock gates so that it could be pumped dry during construction, then flooded to float out a steel platform too large and cumbersome to be moved on land.

Subproject: Roadways and Bridges (SP-8)

Disturbing Activity: Roadway design

In general, good road and rail access are principal requirements for platform fabrication yards. Highways are used mainly for commuter traffic and delivery of supplies, materials, and fuels. Rail or truck transport may deliver large, heavy shipments of steel to the yard. Since the yard requires a waterfront site, road and rail alignment and design are very important considerations for reducing effects on the coastal areas.

Subproject: Groundwater Supply (SP-9)

Disturbing Activity: Groundwater withdrawal

Total water usage depends largely on the production rate of a yard and whether the yard incorporates steel processing into its operations. At a production rate of two to four platforms a year, a yard could require 1,250,000 gallons of water per day if a steel processing or pipe rolling mill were in operation [7]. The Brown and Root plant proposed for Cape Charles, Virginia, which does not incorporate a mill, would use 100,000 gallons of water a day at a production rate of nine platforms per year [14].

Subproject: Stormwater Systems (SP-12)

Disturbing Activity: Stormwater conveyance

Little of a platform fabrication yard is paved; therefore, a large facility would have several hundred acres of bare dirt or gravel surface. For an assumed annual precipitation between 40 and 60 inches, 200 acres might produce 40 to 65 million gallons of runoff per year to be collected and treated by the stormwater runoff system. Runoff turbidity may be reduced through the use of retention basins or settling ponds. The presence of antifouling compounds and other toxic contaminants in the yard may require extensive reconditioning of stormwater before release to coastal waters.

3.6 PIPE-COATING YARDS

3.6.1 Profile

Unless an oil or gas field is far offshore or the yields is low, a pipeline system is usually preferred over tanker transport for economic reasons and because the spill potential is lower. Where pipe is being laid from an offshore field to landfall, a pipe-coating yard will be located at a nearby onshore site. A pipe-coating yard prepares standard 40-foot sections of pipe, usually between 14 and 44 inches in diameter, for installation on the sea floor at depths up to 600 feet or more.

Offshore pipe sections require two outer coatings: one to protect the steel pipe from the corrosive effects of seawater, and another to add sufficient weight to overcome the tendency of the pipeline to float when filled with buoyant oil and gas. After coating, a 40-foot section of the largest-diameter pipe may weight up to 40 tons [7]. Coating on the inside surface of the pipe, which is needed when the oil or gas has a high sulfur content, will normally be applied at the pipe mill and not at the pipe-coating yard. Differing diameter pipe can normally be handled at a single yard without delay.

Normally, pipe sections are sent by rail or ship from a steel mill to the pipe-coating yard where they are coated. The prepared sections are then barged offshore to the "lay-barge", which simultaneously joins the sections and lays the pipe in a virtually continuous operation.

A potential pipe-coating yard site must be flat or nearly so. Additionally, the land must be firm enough to support the weight of concrete-coated pipe, and must have good drainage.

Pipe-coating yards vary considerably in size and complexity. On the one hand, a small, temporary, single-season facility on a 30-acre site may rent equipment and lease land to meet an immediate offshore field demand for 50 miles of pipe or less. On the other hand, a large permanent operation occupying a 75 to 200 acre site may install the most modern coating equipment and environmental control systems to meet a demand for 200 to 400 miles of pipe per pipe-laying season. A season is primarily defined by favorable sea conditions in which the offshore lay-barge can operate. For a Gulf of Mexico yard, a season is about 8 months. Activity at a yard also is related to such non-seasonal factors as progress in OCS field development, and changing production rates that affect pipe demand and delivery schedules and thus cause fluctuations in employment and work loads.

A pipe-coating yard is relatively simple. A permanent yard can be constructed and operational in as few as 6 months (3 months for a temporary yard). Pipe-coating yard components typically include a large open area for pipe storage, rail and marine shipping terminals, separate pipe cleaning and pipe-coating structures, warehouse and repair and maintenance buildings, and an administrative office.

A yard requires a relatively small labor force. During pipe-laying periods a typical yard is active, noisy, and dusty from the frequent handling of large pipe sections and the operations involved with the pipe-coating processes.

The pipe is first scraped, brushed, and either sand- or shot-blasted to remove rust and to provide a clean surface. The next step is the application of an anti-corrosive (asphaltic-aggregate) mastic coating to a preheated pipe, usually in an indoor facility. The pipe is then cooled by spraying the inside with water. Then a whitewash mixture of hydrated lime is applied to the fresh mastic coating. The pipe sections are stored unstacked on the ground until the coat has hardened. The weighting coat of concrete and iron ore is then applied to the pipe while it is simultaneously wrapped with reinforcing galvanized wire mesh. A final curing mixture also is applied. After curing (4 to 24 days) the sections are stacked on a prepared sand bed.

At the end of the one-month coating period, the finished pipe is loaded on supply barges and towed to the lay-barge. A 150-foot barge of 60-foot beam is capable of hauling roughly one-half to one mile of pipeline per trip. Delivery of two miles of pipe per day would represent a normal rate of shipment.

3.6.2 Site Requirements

Major site requirements for a pipe-coating yard include a large tract of level land (75 to 200 acres) with navigational access for pipe and materials transport, and rail and highway access for materials supply. Lesser requirements include proximity to industrial support services, a pipe supply source, an appropriate labor pool, and both water and electrical power supply. Depending on the demand expected, one to three pipe-coating yards may be planned in response to development of a single oil and gas lease area.

Pipe-coating yards have traditionally been located at waterfront sites to facilitate shipment of raw materials into the yard by vessel and to gain direct access to offshore pipe-laying operations. However, the coating and storage operations are not waterfront dependent and could be accomplished inland. Whether this would be practicable depends upon circumstances. Dock frontage is necessary for loading the processed 40-foot lengths of pipe onto barges and for receiving raw materials. However, the frontage could be provided at a separate shipping terminal connected by railway or road to the inland pipe-coating facility. This strategy, in instances where it is practicable, has several benefits: a gain in elevation of the yard (in case of flooding); reduced need for scarce, expensive waterfront land; and lessened ecological disruption along the shoreline.

A typical pipe-coating yard requires 750 feet or more of dock frontage to handle the loading of two supply barges simultaneously [7]. The waterfront terminal may also receive large quantities of raw materials such as sand, cement, and iron ore aggregate for the coating yard operations (Tables 11 and 12). Since, in many circumstances, raw materials and supplies may be shipped more economically overland, access to suitable roads and a railroad is an important siting criterion.

The land area required for a pipe-coating yard is related to the expected demand for pipelines for the OCS field served by the yard. Up to 95 percent of the total developed acreage of a yard is storage space for coated and uncoated pipe and raw materials. About 300 miles of different sized sections of pipe can be stored at a single 100 acre site [7]. Additional area is normally required for a vegetated buffer zone to minimize the effects of noise, dust, and stormwater runoff. Yard sites require soils of moderate load bearing strength to support the weight of concrete-coated pipe and heavy equipment. A land slope of less than 3 percent is normally required.

Moderate quantities of fresh water are needed for the 150 to 200 employees and for such processes as cooling the pipes, mixing the

Table 11. Raw Materials Required per Mile of Pipe Corrosion Protection Coating (Source: Reference 7)

Pipe Diameter (inches)	Nominal Coating Thickness (inches)	Tons of Asphalt	Tons of Aggregate	Pounds of Fiberglass	Gallons of Primer
6	3/8	2.8	25.0	55	26
14	1/2	5.7	50.9	113	66
20	5/8	10.0	90.3	201	92
22	5/8	11.0	99.1	220	106
24	5/8	12.0	107.6	239	119
28	5/8	13.9	125.2	278	132
38	5/8	18.8	168.9	375	185
42	5/8	20.7	186.5	414	198

Table 12. Raw Materials Required per Mile of Pipe Concrete Coating (Source: Reference 7)

Pipe Diameter (in inches)	Pipe Wall Thickness (in inches)	Weight of Cement (in tons)	Weight of Sand (in tons)	Weight of Iron Ore Aggregate (in tons)	Water Required (in 1000 gal.)	Weight of Wire Mesh (in tons)
14	1/4	7.1	120.0	-	0.5	1.5
20	1/4	37.7	200.0	-	2.8	2.5
22	5/16	46.5	-	400.0	3.4	3.0
24	5/16	69.0	-	500.0	5.1	3.5
28	3/8	92.8	-	700.0	6.9	4.5
38	3/8	100.3	-	1,000.0	7.5	5.5
42	3/8	116.4	-	1,200.0	8.7	6.0

whitewash and concrete, and cleaning. Total consumptive water use for pipe coating facilities may vary from 3,000 to 15,000 gallons per day [7]. Wastewater discharge is usually minimized through collection and re-use of water from these processes. Process wastewaters are treated by passing them through a series of settling ponds.

3.6.3 Potential Sources of Disturbance

The greatest potential for adverse effects on fish and wildlife and their habitats is associated with site preparation, roadways and bridges, navigational improvement, and piers. Slightly less grave effects may be caused by site development, stormwater and industrial wastewater systems, solid waste disposal, and bulkheads.

Noise and dust pollution presumably would have small risks of adverse effects on fish and wildlife and their habitats. Nonetheless, pipe cleaning and coating, and general yard activity can generate significant quantities of dust, including cement and rust particles. Dust controls include dust collectors installed in the pipe cleaning structure, in the pipe coating structure, and in the concrete preparation area. Noise levels are reduced by insulating structures and by appropriately modifying equipment. Both dust and noise effects on surrounding areas can be mitigated by use of a vegetated buffer zone around the perimeter of a yard.

Subproject: Navigational Improvement (SP-1)

Disturbing Activities: Dredging and spoil deposition

A key requirement of pipe-coating yards is marine access. The coated pipe must be transported to the offshore field by barges. Uncoated pipe, iron ore aggregate, and other materials arrive by water, wherever feasible. Even where rail or highway transport of heavy material might substitute for supply ships, the necessity of barging the coated pipe offshore requires good navigational access including berth and channel depths of 10 to 15 feet or more. Channels may need to be deepened further (20 to 30 feet) for deep-draft ore ships and other carriers and may need berthing space provided for them. Thus, locating a shipping terminal for the yard at a shallow bay site may require extensive dredging (with its resulting spoil production).

The need for dredging is of particular concern where bulkheaded dock frontage is proposed. In this case, the excavation and accompanying spoil disposal required to bring ships and barges directly alongside the yard may be extensive. On the other hand, less dredging would be required for pipe-coating yards served by a pier, or for those located on deeper bays. Because of the expense of dredging, and of subsequent maintenance dredging, it is advantageous to the owner to locate a pipe-coating yard near an adequate existing channel. For example, in a developed waterfront industrial area or where multiple industries are present, the costs of channel dredging and maintenance usually is borne by the public rather than by a single company.

Subproject: Piers (SP-2)

Disturbing Activity: Pier design

Where the work and storage areas are located back from the shore, piers are often used instead of bulkheaded dock frontage. Piling-supported piers that extend over wetlands as well as out into the water are strongly recommended in place of solid fill structures. The dock or pier frontage requirement depends upon expected pipe shipping volumes. A 750-foot frontage is needed for simultaneous loading of two barges with coated pipe sections. More frontage would be required for additional barges, service craft, and supply ships. A pier normally supports at least one permanent crane, of about 150-ton rating, for loading and offloading pipe and raw materials. To reduce dredging needs, the landward end of the pier may be used for shallow draft barges and the seaward end for ore ships and other deeper draft vessels.

Subproject: Bulkheads (SP-3)

Disturbing Activity: Bulkhead design

Bulkheading is a common practice for waterfront industrial sites of this kind. For a pipe-coating yard, bulkheads are used to: retain fill for extending waterfront land area or leveling the site; control shore erosion, and provide convenient dock frontage that will allow heavy loads to be moved to the water's edge. Where interlocking steel sheet pilings or other vertical bulkhead materials are used, extreme alteration of the shoreline occurs.

Extensive dock frontage is required for a pipe-coating yard (at least 750 feet for two barges). If additional space is needed for offloading raw materials arriving by ship, the required frontage could easily double. It is particularly important that the dockside yard surface be capable of supporting the operation of large portable cranes, forklifts, and other heavy equipment. A bulkheaded waterfront may require elimination of wetlands and excavation of adjacent shallow bottoms to depths of 20 to 30 feet in order to provide berths for pipe barges or supply ships.

Subproject: Site Preparation (SP-5)

Disturbing Activity: Clearing, grading

The pipe storage area (up to 95 percent of the developed part of the site) is cleared completely and graded level. The remaining area may be cleared for buildings, or it may be completely cleared, graded, and landscaped.

Finish grading provides the necessary slopes for drainage of rain runoff. Unless a separate system is provided, polluted water from the pipe-coating process would drain to the same collection points. Buffer areas of natural terrain provided along the edges of watercourses aid soil stability and runoff detention and purification. Those along adjacent property lines reduce noise effects from sand or shot-blasting, pipe handling, and other operations.

Leveling the yard surface may require the use of additional dredged or trucked material to fill depressions, to raise the land surface above flood elevations, or to solve other problems. Most of the work area is left unsurfaced, except for sand bed and sand berm requirements in pipe curing and storage areas.

Where piers are not considered, substantial filling along the shoreline may be needed to backfill behind bulkheads. If the pipe-coating facility is located inland with a road or rail link to a marine loading terminal, this type of filling would be minimal.

Subproject: Site Development (SP-6)

Disturbing Activity: Road construction and utility installation

Access roads are required from main or secondary roads to the property, at which point they may change from paved to unpaved surfaces. Travelways in the yard often are left unpaved to allow greater flexibility in storage and handling of pipe, and to reduce construction expenses.

Underground utility, wastewater, and related systems are "roughed in" during this stage, including excavation, pipe or conduit laying, and regrading of main lines. Provisions are made for sumps, collectors, sediment basins, and other wastewater systems. Excess materials from excavation may require disposal.

Subproject: Roadways and Bridges (SP-8)

Disturbing Activity: Roadway design

Commuting traffic requirements of a pipe-coating yard are moderate, while material shipment by highway may put a comparatively heavy load on the local highway system, particularly in the absence of a railroad connection. The amount of miscellaneous raw material used at a typical yard averages 200,000 tons per year. Traffic volume varies greatly between busy and slack periods. However, daily or weekly deliveries of fuels, cement, primer, and mastic can be expected during periods of full operation.

The pipe to be coated is transported by rail, barge, or ship; because of its weight, highway transport is normally infeasible. Railroad shipment of 250 miles of pipe, the amount processed by a typical yard per year, requires about 4,000 carloads, or 100 cars per week during a 40-week operating season. Rail shipment of the great volumes of iron ore aggregate, sand, cement, and other materials used would increase railroad activity even more. Both the pipe and ore are brought in by ship whereever feasible. Noise impacts from these increased transport systems would be most prominent if the facility moved into a rural area.

Subproject: Stormwater Systems (SP-12)

Disturbing Activity: Stormwater conveyance

Runoff water from pipe-storage areas may pose moderate problems because of the large barren surfaces that are susceptible to erosion. The water may carry a high load of pollutants if not intercepted and treated, including contaminants from pipe-coating materials such as coal tar, urethane, epoxy, silicone enamel, phenolic, and zinc. Separate collection systems for stormwater and cooling and curing process water, with the latter being treated, would reduce the severity of the impact (see SP-14). Runoff rates and the quality of runoff water vary according to soil properties, slope, and yard layout.

Subproject: Solid Waste Disposal (SP-13)

Disturbing Activity: Solid waste disposal

Three major types of solid wastes may be generated by a pipe-coating yard: packaging materials, mastic and cement or process debris, and contaminated wastes. An estimated 5 to 10 tons of wood and paper packaging wastes may be collected each month for disposal [7]. Normally, metal waste will be collected and sold as scrap. Concrete and mastic debris and fragments are not considered to be a major problem because they are frequently reused in the crating process. Solid wastes contaminated by chemicals from the mastic coating (see SP-12 for ingredients) must be treated, incinerated, or buried to prevent reentry of the contaminants into the air or water.

Subproject: Industrial Wastewater Systems (SP-14)

Disturbing Activity: Wastewater disposal

The number of gallons of process water depends upon the production capacity of the yard. Water may be supplied by local municipal sources, or pumped from wells or from adjacent fresh (or slightly saline) water bodies or rivers. The largest amounts of water are used to cool the heated pipe sections after they are coated with mastic (see SP-12 for ingredients) to make a whitewash mixture of hydrated lime, and to mix with cement and aggregate (including iron ore) to make the concrete for the outer coating. The final concrete curing mixture does not use water. Because these processes may contaminate wastewaters with hydrocarbons and alkali and other toxic substances, this water must be treated before release. For example, provisions must be made for pipe cooling water and whitewash to be collected in a sump or basin for treatment. Direct runoff from the yard would carry pollutants to adjacent receiving waters, particularly if the soil has poor permeability. Some pollutants from waste disposal facilities may leach into the ecosystem.

3.7 OIL REFINERIES

3.7.1 Profile

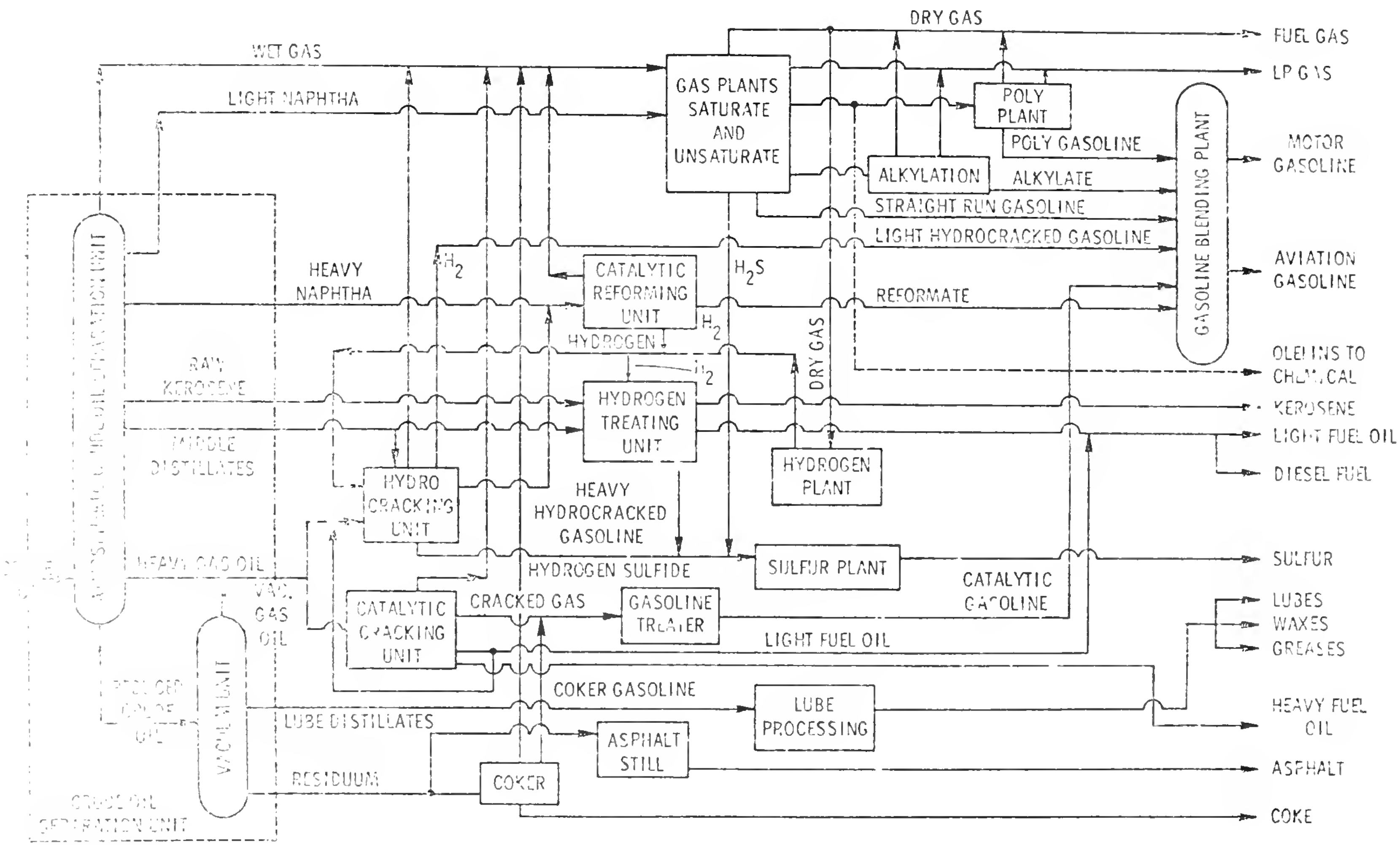
Refineries are large, highly visible industrial facilities which handle highly flammable products, consume large amounts of water, require large tracts of land, and may emit noise and odor pollution as well as large amounts of air pollutants. Because of these and other problems, an oil refinery may be the subject of more public controversy than any other facility involved in OCS oil and gas development. Refineries are one of the three major components of the petroleum products industry along with petrochemical plants and gas processing plants (Section 3.8 and 3.9).

The modern refinery is a complex network of highly automated processing units connected by pipelines, storage tanks, and pumping stations. Refinery components also include: wastewater treatment facilities; ancillary buildings such as administration offices, machine shops, fire stations, and warehouses; and truck and rail terminals. A new refinery may require 3 or more years to build, employing a work force of up to 3,000 during construction. The work force would be reduced to about 550 permanent employees for a 200,000-barrel-per-day (B/D) refinery operating 24 hours per day [7].

A refinery is designed as a series of processing units that separate, convert, treat, or blend crude oil to make such products as gasoline, fuel oil, butane, and coke (Figure 5). Crude oil is brought to a refinery by pipeline or tanker or both and is temporarily stored in tanks. When the crude enters the production stream, it may undergo as many as four distinct processes: (1) separation into light, intermediate, or heavy hydrocarbon groups; (2) conversion to more refined groups by processes which chemically alter the molecules, including polymerization, catalytic reforming, and cracking; (3) treatment, which removes the odorous contaminants such as hydrogen sulfide; and (4) blending of base stocks to produce a wider variety of products. After processing, the products are temporarily stored for later distribution by pipeline, ship, barge, or truck.

If the crude oil supply to the refinery is "sour"--containing greater than 0.5 percent sulphur compounds by weight--a special crude treatment, or "sweetening", may be necessary before it enters the refinery stream.

Figure 5. Typical refinery operations and products (Source: Reference 20).



In the United States, more than half of the existing refineries cannot receive sour crude unless it has been sweetened. Sixty-six percent of United States oil reserves, and 81 percent of world reserves, are estimated to be sour. Therefore, many U.S. sweet crude refineries will probably convert to receive sour crude. The sweetening treatment facility consists of hydro-treating processing units, each with a capacity of 12,000 to 24,000 B/D, and sulfur recovery units. The crude may be processed before shipment or after it arrives at the refinery site. A new sour crude treatment facility can be built in two years or less, on 100 to 200 acres of land [12], at an entirely new site or next to an existing refinery.

In the United States, refinery production rates vary from 500 B/D to 400,000 B/D [21]. Capital investment is very high for a new refinery varying between $1,500 and $3,000 for each B/D of capacity. Refineries are built in response to the demand for refined products and the availability of crude. Expansion of existing capacity is often more economical than constructing a new refinery, since most of the required supply and support services are already in place and economies of scale can be realized.

Refineries may be located anywhere between the source of crude and the intended market area, but are more often built in close proximity to the demand center. Crude oil from U.S. offshore fields is usually piped to the refinery. Foreign crude may be brought directly to the refinery site in large tankers, or piped from a marine terminal to the refinery. Foreign and domestic crude oils are combined at some refineries to make the appropriate mix of crude for their processing units.

3.7.2 Site Requirements

Major siting requirements for a new refinery include a large tract of moderately level land, the availability of large amounts of fresh process water, and an abundant supply of electrical power. A refinery is also located so as to take advantage of the existing petroleum transportation system, particularly the distribution system for the market to be served, and the supply system for crude oil. A refinery is usually located between the marine terminal at which crude arrives and the products market to increase efficiency by keeping the oil moving in one general direction. "Back-hauls" are minimized because transporting oil to a distant refinery and then transporting products back to the market region usually causes a significant economic loss.

The acreage requirements of refineries are difficult to predict because the relationship of refinery size to types of process and to patterns of land use is quite variable. For example, a 250,000 B/D refinery requires roughly 1,000 acres, while a 500,000 B/D unit takes about 1,750 acres [7]. A refinery site plan consists of several major sections including: processing units, service and administration buildings, crude oil and products storage, buffer area, and reserve land for future expansion. The processing units are usually tightly clustered, although some less utilized units may be situated in other areas of the refinery complex.

Because of the potentially hazardous nature of a refinery (fire, explosion, noxious gas) the site requires a geologically stable area. Good soil bearing properties are required to support the heavy processing structures and storage tanks.

A refinery site must have good transportation available, by water or land, or both where possible. Refineries usually have been located along navigable waterways, where they may have marine terminals and loading/ unloading facilities. A waterfront site is not necessary to receive crude oil, since it can easily be offloaded from tankers at a marine terminal and piped to the refinery (see discussion of marine terminals, Section 3.2). However, because refineries use enormous amounts of water for both process needs and cooling, a waterfront site can offer a considerable economic advantage.

Water supply needs vary according to the size of the refinery, types of products manufactured, processing and cooling system technology, and water quality. In newer refineries, fresh water needs are often supplemented by use of brackish water in cooling systems and, to an extent, by air cooling systems. Because of capital costs and high energy usage, air cooling systems are not expected to totally replace the combinations of water and air cooling now in use.

In addition to electric power, refineries use varying amounts of fossil fuel, either oil products refined from crude in the refinery or natural gas removed from the crude stream or piped in from a gas producing field.

3.7.3 Potential Sources of Disturbance

Oil refineries may have a number of major adverse effects on fish and wildlife and their habitats, resulting from their large freshwater demand; appreciable discharges of polluted wastewater; large amounts of solid waste; and site preparation activities during construction. Disturbances and adverse effects may also result from road construction, storm runoff, and electric power needs.

In addition to the refinery, related facilities can cause problems. For example, a refinery usually requires a pipeline connection to a marine terminal or an offshore field, necessitating a pipeline corridor at least 150 feet wide. Navigational improvements may be needed to accommodate deep draft tankers. In some instances the crude stream will have passed through a partial processing facility (Section 3.2) prior to arrival at a refinery where oil and gas are separated from the water which then must be disposed of.

The electrical energy requirements for a refinery vary depending on the complexity and efficiency of the processing units. An efficient refinery may require 2 kilowatt-hours per BBL, while an inefficient one uses up to 9 kilowatt-hours per BBL. A refinery may generate its own electrical power or purchase it from commercial sources. In either case, the additional power generated for the oil refinery also may entail production of more thermal effluent and output of pollutants, with such accompanying problems as entrainment of marine life in cooling waters (a 200,000 B/D refinery may use over 25 million gallons of water per day for cooling).

Although air pollution and noise are assumed to have minor effects on fish and wildlife, these disturbances do have major direct impacts on humans and therefore may be critical in siting, design, construction, and operation of refineries.

Sources of high noise levels at a refinery are compressors, boilers, furnaces, blowers, and cracking unit coolers. A modern refinery, which uses the best available technology for suppressing noise and has an adequate buffer area between its neighbors and processing units, can significantly decrease noise annoyance.

Major emissions to the atmosphere from a refinery may be generated from elements of the processing system, such as cracking and coking units; from machinery, such as boilers and compressors; and from leaks in pipe valves and seals and storage tanks. The concentration of these emissions, which include hydrocarbons, sulfur oxides and particulate matter, depends on the chemical characteristics of the crude oil, the types of processing units, and the pollution control equipment installed. Further air problems originate with releases of vaporized hydrocarbons into the air at transfer points such as marine terminals (Section 3.2). Refinery odor emission sources are storage tanks, hydrocarbon-contaminated wastewater, pipeline leaks, and leaks of liquids and gases from the process units [22].

<u>Subproject: Site Preparation (SP-5)</u>

<u>Disturbing Activity: Clearing, grading</u>

A new refinery site normally requires a large tract of land to provide for initial needs for the plant layout, to provide sufficient buffer area, and to allow future expansion. Often a surprisingly small portion of the area will be cleared and graded for the processing units and storage tanks. For example, the Mobil refinery at Joliet, Illinois, occupies a 1200-acre site, of which 90 acres are used for storage and 65 acres for processing units [7]. The work area, especially, requires an adequate buffer strip to minimize dust and noise problems and to aid in runoff water filtration. There will be little to no wildlife habitat remaining after refinery construction. Some bird and aquatic life may be attracted to water treatment ponds.

Subproject: Site Development (SP-6)

Disturbing Activity: Line construction and installation

Direct coastal waterfront access is not a requirement for refineries. When they are built inland, major site development activities, such as leveling and filling, road construction, and cable and pipeline laying, are presumed to have minimum potential for adverse effects except where watercourses and ecologically vital areas, including endangered species habitats, are involved. In such cases it is necessary to take all appropriate precautions. Provisions must be made for appropriate disposal of surplus excavated materials.

During site development, provisions must be made for underground utilities and for a stormwater collection system. This is especially important for a refinery because of the potential for toxic substances in runoff.

Subproject: Roadways and bridges (SP-8)

Disturbing Activity: Roadway design

In general, rail access and pipeline and barge transport are very important to refinery operations. Highways are used primarily for supplies, light freight, and commuter traffic. Chemicals and other miscellaneous supplies, such as sulfuric acid, inert gases, and dyes, may be delivered by truck, but more often by barge or rail. Refinery products move in rail tank cars, barges, and pipelines to redistribution terminals for delivery to consumers. Trucks may supply refinery products to the immediate local market area. Provisions may be possible to ameliorate rail and roadway noise.

Subproject: Groundwater Supply (SP-9)

Disturbing Activity: Groundwater withdrawal

Total refinery water usage varies greatly, depending upon production rate, type of processing units, and water use efficiency, including the type of cooling system and recycling practices (Table 13). For example, the Gulf Oil Alliance Refinery, with a rated capacity of 200,000 B/D, cycles 28 MMGD for cooling purposes; however, only some of the cycled water is consumed. Evaporation at the Alliance Refinery, for example, is 4 MMGD [7].

The amount of water lost must be "made-up" to maintain constant water volumes. Refineries can reduce water consumption by adopting water recycling methods, such as the use of wash water for dilution purposes, clean condensate water for boiler feed, and secondary treatment water for cooling water purposes. Consumption of fresh water may be reduced at coastal sites by using salt water for cooling. Otherwise, large volumes of

Table 13. Water Consumption Estimated for Several Refineries (Source: Reference 12)

Refinery	Gallons per Minute per 1,000 Barrels per Day	Gallons per Day (100,000)
Water-cooled		
A	110	15,840,000
B	130	18,720,000
C	100	14,400,000
Average	113	16,320,000
Air-cooled		
D	20	2,880,000
Average	30	4,320,000

fresh water are needed from surface water sources or from on-site wells which tap local aquifers.

Subproject: Stormwater Systems (SP-12)

Disturbing Activity: Stormwater collection (design and operation)

Storm runoff from process and storage tank areas of a refinery often contains oil and grease and other toxic substances, and must be collected and treated before discharged to local receiving waters. Because its content of contaminants is similar, this stormwater may be combined with process wastewater for treatment. Large volumes of stormwater may be held in retnetion ponds or tanks until it can be treated and safely discharged.

Subproject: Solid Waste Disposal (SP-13)

Disturbing Activity: Solid waste collection and disposal (design and operations)

Solid wastes that could have major effects on fish and wildlife may be produced by a refinery during oil storage, oil processing, wastewater effluent treatment, and other activities. Wastes generated by these activities can be categorized as process solids, effluent treatment residues, and general waste (see Table 14). A 250,000 B/D refinery may generate 20,000 lbs/day of solid waste [8].

Table 14. Sources and Composition of Refinery Solid Wastes (Source: Adapted from Reference 23)

Source or Process	Wastes	Composition
Processing Solids		
Crude oil storage, desalter	Basic sediments	Iron rust, iron, sulfides, sand, water, oil
Catalytic cracking	Catalyst fines	Inert solids, catalyst particles carbon
Alkylation	Spent sludes	Calcium fluoride, bauxite, aluminum, chloride
Drying and sweetening	Copper sweetening	Copper compounds, sulfides, hydrocarbons
Storage tanks	Tank wastes	Oil, water, solids
Slop oil treatment	Precoat vacuum filter sludge	Oil, diatomaceous earth, solids
Effluent Treatment Solids		
API separator	Separator sludge	Oil, sand, and any of the above processing solids
Chemical treatment	Flocculant	Aluminum or ferric hydroxides, calcium carbonate
Air Flotation	Scums or froth	Oil, solids, flocculants (if used)
Biological treatment	Waste sludges	Water, biological solids, inerts

Wastes containing high concentrations of toxic and combustible contaminants such as water treatment sludges, storage tank "bottoms", and separator sludges, require special collection and disposal methods. Fluid bed incineration has replaced ocean dumping, deep well injection, and evaporative lagoons as the preferred disposal technique for these contaminated sludges. Sludge incineration reduces the volume of solid waste matter because the residual particulate matter is collected from the stack and disposed of in an approved landfill.

Subproject: Industrial Wastewater Systems (SP-14)

Disturbing Activity: Wastewater collection and treatment (design and operation)

The chemical composition of wastewater varies according to the processes employed by a particular refinery. The several million gallons per day that may be used in processing comes in contact with various toxic chemicals. An example of contaminated wastewater loads produced by a typical 100,000 B/D refinery is given in Table 15.

A refinery usually has on-site wastewater treatment facilities. Typical treatment of contaminated wastewaters would include the stripping of sour water, co-mingling and treatment of spent caustics for organic acid separation and neutralization of the water, and recycling of phenolic waters to the desalter for phenol recovery. Wastewater that requires no further treatment is called "clear stream water" and is ready for direct release into receiving waters. Treatment systems must be designed to function efficiently under continuous operation, since a malfunctioning refinery treatment system can release a large amount of pollution in a short time.

Subproject: Industrial Cooling Water Systems (SP-15)

Disturbing Activity: Circulation of cooling water

Of the total volume of water required daily by a refinery, roughly 80 to 85 percent is used for cooling. "Once-through" cooling systems produce maximum heat discharge to the water (thermal pollution) and induce maximum entrainment of marine organisms in the intake stream. Recirculating cooling systems, employing cooling towers or ponds which release the heat to the air rather than to the water, can be substituted. Recirculation, reuse, and release of heat to the air has a lesser cooling water demand and produces less effluent. Anti-corrosion and fouling chemicals, including chlorine and chromium, which are added to cooling water to protect the tower and the condenser system, are highly toxic and require proper collection and treatment. However, due to evaporative losses, concentrations of dissolved substances and suspended particles increase with each passage of water through the system. Refineries that

Table 15. Water Pollution Loads for a Typical 100,000 Barrel per Day Integrated Refinery at Two Different Levels of Treatment (Source: Reference 12)

Water Pollutant	Treatment Level	
	Presently Accepted (lbs/day)	Advanced (Presently Available) (lbs/day)
BOD	1,200	400
COD	7,300	2,000
Oils	800	250
Total Dissolved Solids	45,000	45,000
Suspended Solids	3,500	600
Ammonia (as N_2)	400	40
Chromium	5	3
Phenol	50	5
Sulfides	10	2

draw cooling water from estuaries, lakes, and streams ordinarily use recirculating systems to prevent significant ecological disturbance of these critical water areas.

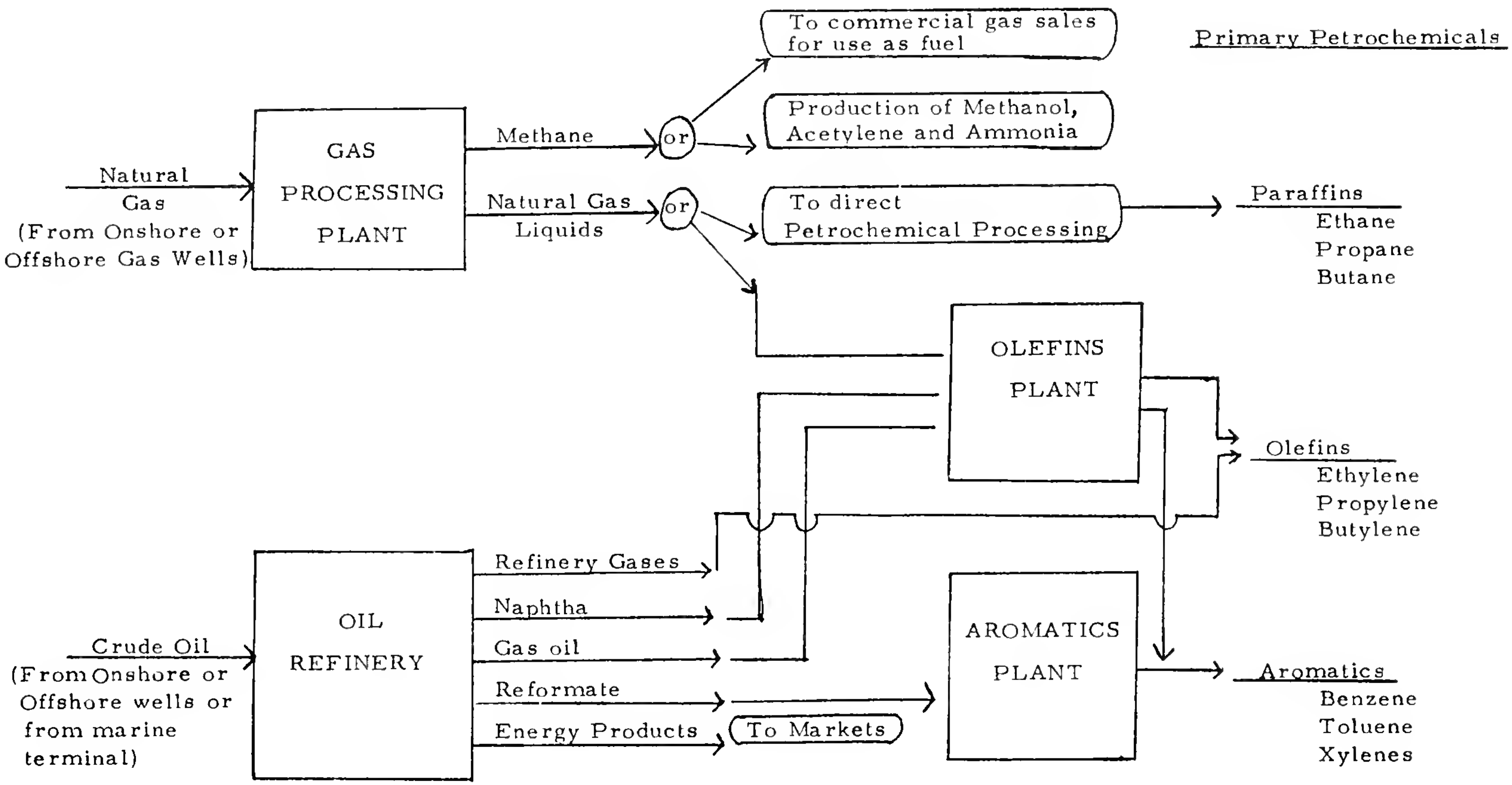
3.8 PETROCHEMICAL INDUSTRIES

3.8.1 Profile

Petrochemical plants are major consumers of natural gas liquids and refinery products, such as naphtha and gas oil. They convert these "feedstocks" into several hundred intermediate and final products, including ammonia, ethane, argon, hydrogen gas, fertilizers, neoprene rubber, aromatics, and ethylene (Figure 6). Petrochemicals as a class exclude fuels, such as gasoline, natural gas, kerosene, and coke, and lubricating oil and similar directly consumable products.

In general, petrochemical plants have a "refinery look" with their typical mass of plumbing. They are highly visible industrial complexes

Figure 6. Derivation of principal primary petrochemicals (Source: Reference 24).



that may heavily stress local land and water resources and cause major problems with noise, odor, and pollution.

New petrochemical plants are often located near existing plants, refineries, and gas processing plants because of the favorable economics of a nearby source of feedstock, the advantage of concentrated services and labor force, and the value of local acceptance. (For example, the Arco Chemical Company located a new ethylene plant on 250 acres of an existing 2,000 acre petrochemical complex in Texas.) [24]

A petrochemical plant may vary in size from a modest extension of an oil refinery to an independent operation located on a 200-acre to 1,000-acre site. Plant production may range from a capacity as low as 500 B/D to over 50,000 B/D. Initial investment costs are estimated at $250 million to $350 million, with a construction period of 2 to 3 years [24, 12, 15].

The major components of a petrochemical plant are: (1) the processing area, which includes feedstock preparation units, chemical reactors, product separators, and purification units; (2) areas for energy production, and water supply and treatment systems; (3) administrative areas, including laboratories, control buildings, parking lots, and (4) buffer areas and areas for future expansion.

3.8.2 Site Requirements

Siting requirements for a major petrochemical plant include a large supply of fresh water, an extensive tract of land, a large amount of fuel and electric power; and a receptive community. The site also must have geological stability because of the potential hazards (fire, explosion, noxious gas) of a petrochemical plant. Proximity to a source of feedstock is an important siting consideration, since large volumes of feedstock are required and transportation costs are high. The availability of supporting physical infrastructure, in terms of transportation, communications, housing, necessary services and maintenance industries, is a major siting requirement.

The close correlation between numbers of refineries and petrochemical plants in the Gulf Coast states is shown below [12].

	Refineries	Petrochemical Plants
Texas	20	86
Louisiana	9	44
Florida (Gulf of Mexico)	1	4

A typical major petrochemical plant requires 200 to 350 acres of land [24]. Strong load-bearing soils are required for the processing and storage tank areas. Petrochemical plants usually are located next to refinery complexes at waterfront sites; however, a petrochemical plant has no direct need for a coastal waterfront location. Appropriate tracts of land away from the waterfront are preferred petrochemical plant sites, offering the advantage of lower costs for land, elimination of shoreline ecological disruption, and lessened risk of pollution.

Freshwater requirements may be a limiting factor where water supplies are scarce. Water needs for a petrochemical plant vary with plant capacity, types of processes, and the characteristics of cooling systems. Estimates of water needs range from 7 to 24 MMGD for large petrochemical plants, and as low as 0.5 MMGD for a small ancillary plant [24]. Improved water-use technology should permit reduction of water consumption by as much as 50 percent by year 1985 and an additional 20 percent by 2000 [25].

Electric power requirements range from 450 to 600 million kwh a year for major petrochemical plants, equal to the power needs of as many as 75,000 people.

Fuel availability is also an important requirement. Fuel oil consumption may be approximately 8,700 B/D [8]. In addition, natural gas (often used as boiler fuel in petrochemical plants), available at a low price, has attracted new petrochemical plants to the Gulf Coast.

Adequate road access to the site is required for materials and commuter traffic. During construction, which may take up to 3 years, the work force may reach 2,500.

In most instances, the plant will receive feedstock through pipelines, and depending on distance to the market and volume of products, pipelines may also carry some of the products. A pipeline corridor of at least 150 feet width may be required to link the petrochemical plant to either a gas processing plant or a refinery (see Overland Transmission Systems, Subproject 11). Rail and truck transportation may deliver materials and chemicals to the plant and deliver petrochemical products to the market, especially to local market areas.

3.8.3 Potential Sources of Disturbance

Petrochemical plants, like other major facilities related to petroleum development, may produce a number of adverse effects on fish and wildlife and their habitats. Major impact-generating factors include large freshwater demand, large volumes of wastewater effluents, large volumes of solid waste, extensive site preparation, and great runoff potential. Many other sources of disturbance to fish and wildlife may become significant, such as electric power requirements and hazardous chemical spills.

Air pollution, noise, and odors from petrochemical plants probably have only minor effects on fish and wildlife. However, these disturbances do directly affect people and are major considerations in the siting, design, construction, and operation of petrochemical plants.

Atmospheric emissions from petrochemical plants vary widely in terms of quantity and type. Quantities depend on the volume of flow through the plant, the types of chemical compounds produced, plant complexity, and the kinds of air pollution abatement equipment used. Major process emissions from a typical plant are toluene, propylene, styrene, and polyethylene. Furnace and cracking operations can release large quantities of carbon monoxide. Machinery and equipment, including heaters and generators, are also major sources of emissions. Evaporative hydrocarbon emissions from fuel storage tanks, and leaks from pipelines, valves, and seals also contribute to air emission problems. Petrochemical plant emissions become more critical when they mix with those from adjacent petrochemical plants, refineries, and gas processing plants.

Major sources of noise at petrochemical plants are air coolers, blowers, compressors, and furnaces. Noise levels from this equipment can be controlled by the use of mufflers, modifications in design, or enclosures. The effects of unpleasant odors can be mitigated by site selection, provision of buffer areas, and design techniques.

Subproject: Site Preparation (SP-5)

Disturbing Activity: Clearing, grading

Clearing and grading the large areas required for major petrochemical complexes may produce disturbances such as soil erosion and loss of prime habitat. Much of the facility requires a level grade and will be surfaced. Roughly 40 percent of a petrochemical plant site is used for processing units and related equipment, and 10 percent for storage tanks. The remaining 50 percent of the site contains ancillary structures, road, rail and pipeline access, buffer areas, and space for future expansion. The work areas usually require buffer strips to minimize dust and noise problems and to aid in water runoff filtration.

Subproject: Site Development (SP-6)

Disturbing Activity: Line construction and installation

During site development, provisions are made for stormwater collection systems, which are most important for petrochemical plants because of the extent of surface area used and the potential for polluted runoff. These systems include settlement and treatment facilities because of the likelihood of high concentrations of heavy metals and other toxic substances in the runoff.

Since petrochemical plants do not require waterfront locations, inland site preparation activities, including leveling and filling, road construction, and cable and pipeline laying, probably have minimal adverse effects. However, important natural watercourses and vital areas of terrestrial ecosystems, including endangered species habitats, may be involved.

Subproject: Groundwater Supply (SP-9)

Disturbing Activity: Groundwater withdrawal

The volume of water needed by a petrochemical plant depends on the type of processing and cooling systems utilized, and the plant capacity. For a large and varied multiple plant complex, total water supply requirements may reach 24 MMGD (Table 16). Large demands for groundwater

Table 16. Estimated Water Requirements for a Representative Petrochemical Complex (Source: Reference 25)

Petrochemical	Annual Output (Million lbs)	Daily Water Use (Million GPD)
Orthoxylene	139	0.4
Toluene		
Xylenes	2,150	1.8
Benzene		
Styrene	380	3.0
Ethylbenzene	87	0.5
Ethylene	1,560	6.0
Propylene		
Butadiene	194	0.5
Butylene		
Cumene		
Phenol	520	0.8
Acetone		
Polyethylene	90	0.3
Ethylene Glycol	200	1.6
Vinyl Chloride Monomer	500	4.0
Polypropylene	70	0.2
Oxo Alcohols	245	1.3
Acrylonitrile	100	1.9
Cyclohexanone	237	1.6
Total	6,472	24.0 (approx.)

withdrawal can lead to overpumping of aquifers, causing land subsidence and, in coastal areas, saltwater intrusion. According to one estimate, petrochemical plant water supply needs can be reduced by up to 50 percent by 1985 through the adoption of water recycling methods, and process techniques requiring lower water volumes [25].

New petrochemical plants that propose to draw cooling water from surface waters--estuaries, lakes, or rivers--normally are required to use closed cycle systems to reduce water consumption, to prevent disturbances to critical water areas, and to prevent cooling water from coming in contact with hydrocarbons.

Subproject: Stormwater Systems (SP-12)

Disturbing Activity: Stormwater conveyance

Runoff may be contaminated with heavy metals, detergents, paints, spilled fuels, and other toxic chemicals. Special runoff collection systems may be provided for areas with the most contamination. This runoff then can be treated and discharged along with process water. Standard stormwater runoff systems are provided for areas of lesser pollution potential, and may require retention ponds or special holding tanks to store the water for treatment before release. Federal runoff pollution standards applicable to the petrochemical industry are in Table 17.

Table 17. Effluent Limitations for Stormwater Runoff New Source Federal Standards in Pounds/Thousand Gallons of Flow (mg/l) (Source: Reference 26)

Characteristic	Maximum for Any One Day	Average Daily Values for 30 Consecutive Days Shall Not Exceed:
Biochemical Oxygen Demand (5 day test)	0.400 (50)	2.210 (25)
Chemical Oxygen Demand	3.10 (371)	1.60 (191)
Solids	0.27 (32)	0.17 (20)
Oil and Grease	0.126 (15)	0.067 (8)
pH	Within range of 6.0 - 9.0	

Subproject: Solid Waste Disposal (SP-13)

Disturbing Activity: Solid waste disposal

Solid wastes from major petrochemical plants originate in feedstock processing, treatment of wastewater, and storage of feedstock and produced chemicals. Sediments from the bottom of the storage tanks, in the form of sludges and slurries, require special handling and treatment prior to disposal. Solid wastes containing potentially hazardous compounds from processing and wastewater treatment procedures also require special collection and disposal methods to prevent contamination of ground and surface waters. Residue from the waste treatment is usually deposited in a sanitary landfill. The types of wastes and their sources and characteristics may vary greatly from one petrochemical complex to another, depending upon the particular processes employed (Table 18).

Subproject: Industrial Wastewater Systems (SP-14)

Disturbing Activity: Wastewater collection and disposal

Wastewaters from petrochemical plants vary greatly in their chemistry and in the treatment required, depending on the chemical characteristics and complexity of plant processes. The two major sources of contaminated wastewaters (in addition to cooling waters) are boiler operations and process waters. In a petrochemical plant, process waters are the most highly contaminated, requiring on-site wastewater treatment (Table 19). They are generated by various steps in the production of petrochemicals such as acidic and caustic washes that remove contaminants from the process stream, washing and scrubbing procedures that remove remaining contaminants, and solvent processes that purify the feedstock and products. Wastewater treatment facilities require careful monitoring because petrochemical production is a continuous 24-hour per day operation and any malfunction of the treatment system can cause a rapid release of large volumes of toxic wastes.

Subproject: Industrial Cooling Water Systems (SP-15)

Disturbing Activity: Cooling water treatment and discharge

Cooling water may account for 40 to 80 percent of the wastewater volume from a petrochemical plant. Cooling waters may contain contaminants from process valve and seal leaks and from additives such as sulfuric acid, chromate, and chlorine, which are added to the cooling water to inhibit corrosion. Once-through cooling systems use the largest volumes of water, and thus produce the maximum volume of heated effluent. Closed-cycle or recycling cooling systems, in which water is cooled in towers or ponds and then reused, require much smaller volumes of water (perhaps 10 percent or less) and consequently generate less effluent. Effluents from petrochemical plants are regulated through the National

Table 18. Sources and Characteristics of Petrochemical Solid Waste (Source: Reference 23)

Source or Process	Wastes	Composition
Processing Solids		
Catalytic cracking	Catalyst fines	Inert solids, catalyst particle carbon
Alkylation	Spent sludges	Calcium, fluoride, bauxite, aluminum chloride
Storage tanks	Tank waste	Oil, water, solids
Effluent Treatment Solids		
API separator	Separator sludge	Oil, sand, and any of the above process solids
Chemical treatment	Flocculant-aided precipitates	Aluminum or ferric hydroxides calcium carbonate
Air flotation	Scums or froth	Oil, solids, flocculants (if used)
Biological treatment	Waste sludges	Water, biological solids, inerts
Water treatment plant	Water treatment	Calcium carbonate, alumina, ferric oxide, silica
General Waste		
Office	Waste paper	Paper, cardboard
Cafeteria	Food wastes (garbage)	Putrescible matter, paper
Shipping and Receiving	Packaging materials, strapping pallets, cartons, returned products, cans, drums	Paper, wood, some metal, wire
Boiler plant	Ashes, dust	Inert solids

Table 19. Petrochemical Processes as Waste Sources
(Source: Reference 27)

Process	Source	Pollutants
Alkylation: Ethylbenzene		Tar, Hydrochloric Acid, Caustic Soda, Fuel Oil
Ammonia Production	Demineralization	Acids, Bases
	Regeneration, Process Condensates	Ammonia
	Furnace Effluents	Carbon Dioxide, Carbon Monoxide
Aromatics Recovery	Extract Water	Aromatic Hydrocarbons
	Solvent Purification	Solvents - Sulfur Dioxide, Diethylene Glycol
Catalytic Cracking	Catalyst Regeneration	Spent Catalyst, Catalyst Fines (Silica, Alumina Hydrocarbons, Carbon Monoxide, Nitrogen Oxides)
	Reactor Effluents and Condensates	Acids, Phenolic Compounds, Hydrogen Sulfide Soluble Hydrocarbons, Sulfur Oxides, Cyanides
Catalytic Reforming	Condensates	Catalyst (particularly Pt, Mo), Aromatic Hydrocarbons, Hydrogen Sulfide, Ammonia
Crude Processing	Crude Washing	Inorganic Salts, Oils, Water Soluble Hydrocarbons
	Primary Distillation	Hydrocarbons, Tars, Ammonia, Acids, Hydrogen Sulfide
Cyanide Production	Water Slops	Hydrogen Cyanide, Unreacted Soluble Hydrocarbons
Dehydrogenation		
Butadiene Prod. from n-Butane and Butylene	Quench Waters	Residue Gas, Tars, Oils, Soluble Hydrocarbons
Ketone Production	Distillation Slops	Hydrocarbon Polymers, Chlorinated Hydrocarbons, Glycerol, Sodium Chloride
Styrene from Ethylbenzene	Catalyst	Spent Catalyst (Fe, Mg, K, Cu, Cr, Zn)
	Condensates from Spray Tower	Aromatic Hydrocarbons, including Styrene, Ethyl Benzene, and Toluene, Tars
Desulfurization		Hydrogen Sulfide, Mercaptans
Extraction and Purification		
Isobutylene	Acid and Caustic Wastes	Sulfuric Acid, C_4 Hydrocarbon, Caustic Soda
Butylene	Solvent and Caustic Wash	Acetone, Oils, C_4 Hydrocarbon, Caustic Soda, Sulfuric Acid
Styrene	Still Bottoms	Heavy Tars
Butadiene Absorption	Solvent	Cuprous Ammonium Acetate, C_4 Hydrocarbons, Oils
Extractive Distillation	Solvent	Furfural, C_4 Hydrocarbons
Halogenation (Principally Chlorination)		
Addition to Olefins	Separator	Spent Caustic
Substitution	HCl Absorber, Scrubber	Chlorine, Hydrogen Chloride, Spent Caustic, Hydrocarbon Isomers and Chlorinated Products, Oils
	Dehydrohalogenation	Dilute Salt Solution
Hypochlorination	Hydrolysis	Calcium Chloride, Soluble Organics, Tars
Hydrochlorination	Surge Tank	Tars, Spent Catalyst, Alkyl Halides

continued

Table 19.(Concluded)

Process	Source	Pollutants
Hydrocarboxylation (OXO Process)	Still Slops	Soluble Hydrocarbons, Aldehydes
Hydrocyanation (for Acrylonitrile, Adipic Acid, etc.)	Process Effluents	Cyanides, Organic and Inorganic
Isomerization in General	Process Wastes	Hydrocarbons; Aliphatic, Aromatic, and Derivative Tars
Nitration		
Paraffins		By-Product Aldehydes, Ketones, Acids, Alcohols, Olefins, Carbon Dioxide
Aromatics		Sulfuric Acid, Nitric Acid, Aromatics
Oxidation		
Ethylene Oxide and Glycol Manufacture	Process Slops	Calcium Chloride, Spent Lime, Hydrocarbon Polymers, Ethylene Oxide, Glycols, Dichloride
Aldehydes, Alcohols, and Acids from Hydrocarbons	Process Slops	Acetone, Formaldehyde, Acetaldehyde, Methanol, Higher Alcohols, Organic Acids
Acids and Anhydrides from Aromatic Oxidation	Condensates Still Slops	Anhydrides, Aromatics, Acids Pitch
Phenol and Acetone from Aromatic Oxidation	Decanter	Formic Acid, Hydrocarbons
Carbon Black Manufacture	Cooling, Quenching	Carbon Black, Particulates, Dissolved Solids
Polymerization, Alkylation	Catalysts	Spent Acid Catalysts (Phosphoric Acid), Aluminum Chloride
Polymerization (Polyethylene)	Catalysts	Chromium, Nickel, Cobalt, Molybdenum
Butyl Rubber	Process Wastes	Scrap Butyl, Oil, Light Hydrocarbons
Copolymer Rubber	Process Wastes	Butadiene, Styrene Serum, Softener Sludge
Nylon 66	Process Wastes	Cyclohexane Oxidation Products, Succinic Acid, Adipic Acid, Glutaric Acid, Hexamethylene, Diamine, Adiponitrile, Acetone, Methyl Ethyl Ketone
Sulfation of Olefins		Alcohols, Polymerized Hydrocarbons, Sodium Sulfate, Ethers
Sulfonation of Aromatics	Caustic Wash	Spent Caustic
Thermal Cracking for Olefin Production (including Fractionation and Purification)	Furnace Effluent and Caustic Treating	Acids, Hydrogen Sulfide, Mercaptans, Soluble Hydrocarbons, Polymerization Products, Spent Caustic, Phenolic Compounds, Residue Gases, Tars and Heavy Oils
Utilities	Boiler Blow-down	Phosphates, Lignins, Heat, Total Dissolved Solids, Tannins
	Cooling System Blow-down	Chromates, Phosphates, Algicides, Heat
	Water Treatment	Calcium and Magnesium Chlorides, Sulfates, Carbonates

Pollution Discharge Elimination System program enforced by EPA and individual states. The sources and concentrations of contaminants in cooling water effluent for a typical petrochemical plant are tiven in Table 20.

Additional major cooling water problems related to petrochemical plants may occur where electrical power is generated to meet the needs of the plant.

3.9 GAS PROCESSING PLANTS

3.9.1 Profile

Gas processing plants are designed to remove impurities such as carbon dioxide and hydrogen sulfide, and to recover valuable liquid hydrocarbons such as methane, butane, and propane, from raw gas streams before they enter commercial gas distrib ution systems.

Natural gas passes through several stages of processing from the time it is produced at the wellhead until it enters a commercial distribution system. If the raw gas stream contains much oil or water, these are usually separated from the gas on the production platform. The oil m ay be pumped ashore; the water is treated to remove hydrocarbons and then discharged into the sea. The separated gas is pumped to shore through a separate pipeline for processing at a gas plant.

At the gas plant, three alternative processes may be used to recover natural gas liquids from a gas stream: (1) lean oil absorption; (2) mechanical refrigeration, and (3) cryogenic refrigeration. The oldest and most common is the lean oil absorption process, in which the gas stream bubbles through a gas-oil medium, similar to kerosene, which absorbs the natural gas liquids. The natural gas liquids are then stripped from the "medium" by heating in another vessel. In the mechanical refrigeration process, the gas stream is cooled (typically to -40^{O}F), which causes the liquefiable hydrocarbons to condense. The cryogenic process cools the gas stream (typically to -150^{O}F) through the use of compressors and turbo-expanders, resulting in greater recovery rates for the lighter liquefied hydrocarbons such as ethane and propane [7]. Gas plants may utilize a single process or, more commonly, a combination of them.

Modern gas processing plants are highly automated. Their capaçity may range from 2 MMCFD to 2 BCFD. There are no standard sizes or designs for gas processing plants; a plant is specifically designed for the volume and composition of the gas stream it processes.

Gas processing plants require relatively small tracts of level land, but often much larger tracts are acquired to provide space for buffer zones and for possible future expansion. A gas plant's principal components include storage tanks, separators, processing units, fractionators, and gas transmission lines.

If a gas stream is "sour" (high sulfur content), a "sweetening" treatment process is needed to remove the sulfur compounds (particularly hydrogen sulfide gas) before the gas can be sold. The treatment may take place at the gas processing plant or at a separate sulfur treatment and recovery facility. If only a small volume of hydrogen sulfide is removed from the natural gas, commercial sulfur recovery is unprofitable and the hydrogen sulfide is flared or incinerated as a waste product.

Table 20. Composition of Cooling Water Effluent of Petrochemical Plants (Source: Reference 29)

Water Sources	Total Waste-water (%)	Flow Range (gpm)	Sources	Potential Pollutants: Type	Potential Pollutants: Concentration Range (mg/1)
Cooling Water (excluding sea water)	40-80	100-10,000 (500-200,000 gal. water/ton product)	Process Leaks: Bearings, Exchangers, Etc.	Extractables	1-1,000
				Mercaptans	
				Sulfides	
				Phenols	0-1,000, but usually less than 1 ppm
				Cyanide	
				Misc. N compounds	
				Acids	
			Water Treatment	Chromate	0-60
				Phosphate	0-60
				Heavy metals	0-30
				Fluoride	0-10
				Sulfate	100-10,000
				Biocides, algicides	0-50
				Misc. organics	0-100
			Scrubbed from Air through Tower	Hydrogen sulfide	
				Sulfur dioxide	0-1,000
				Oxides of nitrogen	
				Ammonia	
				Particulates	0-300
			Make-up Water	Total dissolved solids	100-5,000

If a gas stream contains sufficient valuable liquid hydrocarbons, they are recovered and sold separately. A fractionation facility is needed to separate the recovered liquid hydrocarbons into commercial products such as gasoline and propane. The fractionation facility may be located at the gas plant or at another site connected by pipelines.

3.9.2 Site Requirements

Major factors considered in siting a gas processing plant are the advantages of a coastal location, and the plant's high demands for water and energy. A gas processing plant must be sited between the gas pipeline landfall and a commercial gas transmission line. Gas plants are normally sited as close as possible to the landfall, mainly because of the need to separate heavier hydrocarbons from the gas stream as quickly as possible to minimize plugging or fouling of the pipeline. Thus, gas plants have been primarily located in the coastal zone; however, they are not waterfront dependent and they can easily be located back from the shoreline for ecological or other reasons.

A typical gas processing plant, of 1 BCFD capacity, requires 50 to 75 acres of level, well-drained land. The amount of land required for the basic gas plant layout is related generally to the volume of gas to be processed. The actual area needed for gas processing and storage is typically small, while that reserved for a buffer zone and plant expansion is usually large. A typical plant occupying 75 acres would probably utilize only 20 acres for process structures and other buildings [7].

The availability of cooling water may limit the size of a gas processing plant that can be built on a site. Water needs vary depending primarily on the type of cooling system. Air cooling systems require less water than water cooling systems. Water demands may range from insignificant quantities to 750,000 GPD; a typical plant uses approximately 200,000 GPD. A 500 MMCFD capacity gas plant with closed cycle cooling probably would require about 15,000 GPD of makeup water [12].

Electric energy requirements are high enough to be a limiting factor in certain situations. A 1 BCFD capacity gas plant would use 5.4 million kwh/month of electric power. This plant would also use 360 MMCF/month of natural gas from its feedstock to fuel heaters and compressors.

Rail, truck, barge, and pipeline transport are used for gas plant products. The mode of transportation required is specific to each plant, depending on location of markets, types of products, and available transportation systems.

3.9.3 Potential Sources of Disturbance

Potential sources of major adverse effects on fish and wildlife from gas processing plants include freshwater demand, contaminated wastewater and solid wastes, and site development activities. Stormwater runoff and cooling system effluents also may affect fish and wildlife.

Additional potential sources of disturbance are associated with related, dependent facilities. Pipelines are particularly important because a gas processing plant requires a pipeline connection directly from the production platform or from a marine terminal. It may also be linked by pipeline to partial processing facilities or pressurized gas storage facilities. The potential effects of onshore pipelines, marine terminals, and offshore pipelines are reviewed in Sections 3.1, 3.2, and 3.3 respectively.

Emissions to the atmosphere and noise probably have only minor effects on fish and wildlife, but these disturbances do have important effects on people and, therefore, may be critical in siting, design, construction, and operation of gas processing plants.

Emissions from a gas processing plant may come from processing units, evaporation, flaring, and equipment such as boilers and compressors. Effects from the emissions vary, depending on the composition of the gas stream, the types of processing units, the pollution control equipment, and the regional ambient air conditions. Emissions may include hydrogen sulfide, sulfur oxides, hydrocarbons, particulates, carbon monoxide, and nitrogen oxides.

Major sources of noise from gas plants, which operate 24 hours a day, include compressors, boilers, scrubbers, and flare stacks. Gas plants are required by Federal pollution laws to use the best available technology for suppressing noise. Where gas is stored underground in salt domes, the discharge of brine solution to create storage caverns may also be a pollutant.

Subproject: Site Preparation (SP-5)

Disturbing Activity: Clearing, grading

Site preparation and development for a new gas processing plant usually involves a relatively small amount of land. Around 20 acres may be cleared with any additional land left to act as a buffer zone and to allow for future expansion. Since the major waterfront need is for a pipeline landfall, gas processing plants can be built inland if coastal siting poses a threat of damage to wetlands or other environmental problems. If an inland site is selected, land clearing and grading for the processing units, operations buildings, and storage tanks should have minimum potential for creating disturbances that would affect coastal fish and wildlife. In upland areas, site preparation activities, such as grading and filling, road construction, and cable and pipeline laying, have few adverse effects if standard erosion control and other precautions are taken. The work area usually requires an adequate buffer zone to minimize dust and noise problems and to aid in filtering runoff water.

Subproject: Site Development (SP-6)

Disturbing Activity: Line construction

The site development plan must provide for underground stormwater collection systems and wastewater disposal systems because of the high potential for toxic spills and contamination at a gas processing plant. Other services including high capacity electric power lines must also be provided.

Subproject: Groundwater Supply (SP-9)

Disturbing Activity: Groundwater withdrawal

Gas processing plants require about 1.5 gallons of water per thousand cubic feet of gas processed [7]. Water demand for partial processing facilities included in a gas plant complex is negligible. While the overall water demand for a gas plant, is relatively low when compared to other major petroleum development facilities, precautions must be taken to avoid environmental disturbances from excessive groundwater withdrawal.

Subproject: Stormwater Systems (SP-12)

Disturbing Activity: Stormwater conveyance

Stormwater runoff from the process areas of a gas processing plant is likely to be contaminated and should be collected and treated before discharge. Potential hazardous contaminants include liquid hydrocarbons, oils, and other toxic chemicals. In addition, liquid feedstock and product transfer systems (such as pipelines) on the site have an appreciable potential for leaks and spills, requiring that berms and other containment systems be provided along with adequate capacity in the collection system to handle the maximum expected contaminant load. Where contamination of the yard surface by toxic matter is routine, a separate runoff collection system with special treatment facilities is necessary.

Subproject: Solid Waste Disposal (SP-13)

Disturbing Activity: Solid waste disposal

Solid wastes from gas processing plants include processed sludge from brine evaporation, residuals from accidental spills, and general office and packaging materials. Solid wastes containing toxic and combustible contaminants such as scale and sludge from cleaning boilers, storage tank cleaning sludge, iron oxide, and wood chips used to sweeten sour gas streams, and contaminated sulfur, require special collection and disposal methods.

Subproject: Industrial Wastewater Systems (SP-14)

Disturbing Activity: Wastewater disposal

Wastewaters from gas processing plants include process water, boiler wastewater, and cooling water which accounts for 70 to 100 percent of the total [7]. Wastewater contaminants include: chromium, zinc, and chlorine for cooling waters; dissolved hydrocarbons, heavy metals, grease, and other toxic compounds for process waters; and phosphates, sulfite, and tannin for boiler wastewaters. Wastewater treatment programs must be designed to meet the conditions of specific gas processing plants. Domestic wastewater is not a significant factor in wastewater loads because of the small number of employees. Wastewater treatment systems should be designed to function efficiently under continuous operation, (a malfunction can release large amounts of pollutants in a short time) and suitable "backup" capacity should be available.

Subproject: Industrial Cooling Water Systems (SP-15)

Disturbing Activity: Circulation of cooling water

Cooling system designs for gas processing plants may use air or water heat exchange or a combination of the two. Where water is used, closed-cycle systems are better than open cycle (once-through) designs. The once-through systems generate maximum water demand, produce maximum volumes of heated effluent, and cause the greatest disturbances to the aquatic environment. Closed-cycle (recirculating) water cooling designs, which employ cooling towers or ponds, generate far less effluent and reduce water demand. However, chemicals such as hypochlorite that are added to cooling water to reduce corrosion in cooling towers and condenser systems are highly toxic and require collection and treatment.

3.10 LIQUEFIED NATURAL GAS SYSTEMS

3.10.1 Profile

Liquefied natural gas (LNG) systems provide a convenient means for transporting gas over distances too great for pipelines. They are expensive to build and operate, and are only economically feasible where there is high demand for gas and the source area has an abundant supply of gas. The market situation in the United States in recent years has been one of increasing demand for domestic gas and declining production.

The two phases in an LNG system are liquefaction for transport and regasification for the market. Liquefaction plants are located as near as possible to a gas field. They receive gas piped from the field, remove impurities, and successively cool and compress the gas until it is below the boiling temperature of minus 260°F. This causes a more than 600-fold reduction in volume and converts the gas into a liquid. From this point until the time of regasification, the liquefied natural gas must be maintained under constant low temperatures and high pressures. From the liquefaction plant, the LNG is loaded into a specialized tanker for transport to the regasification site.

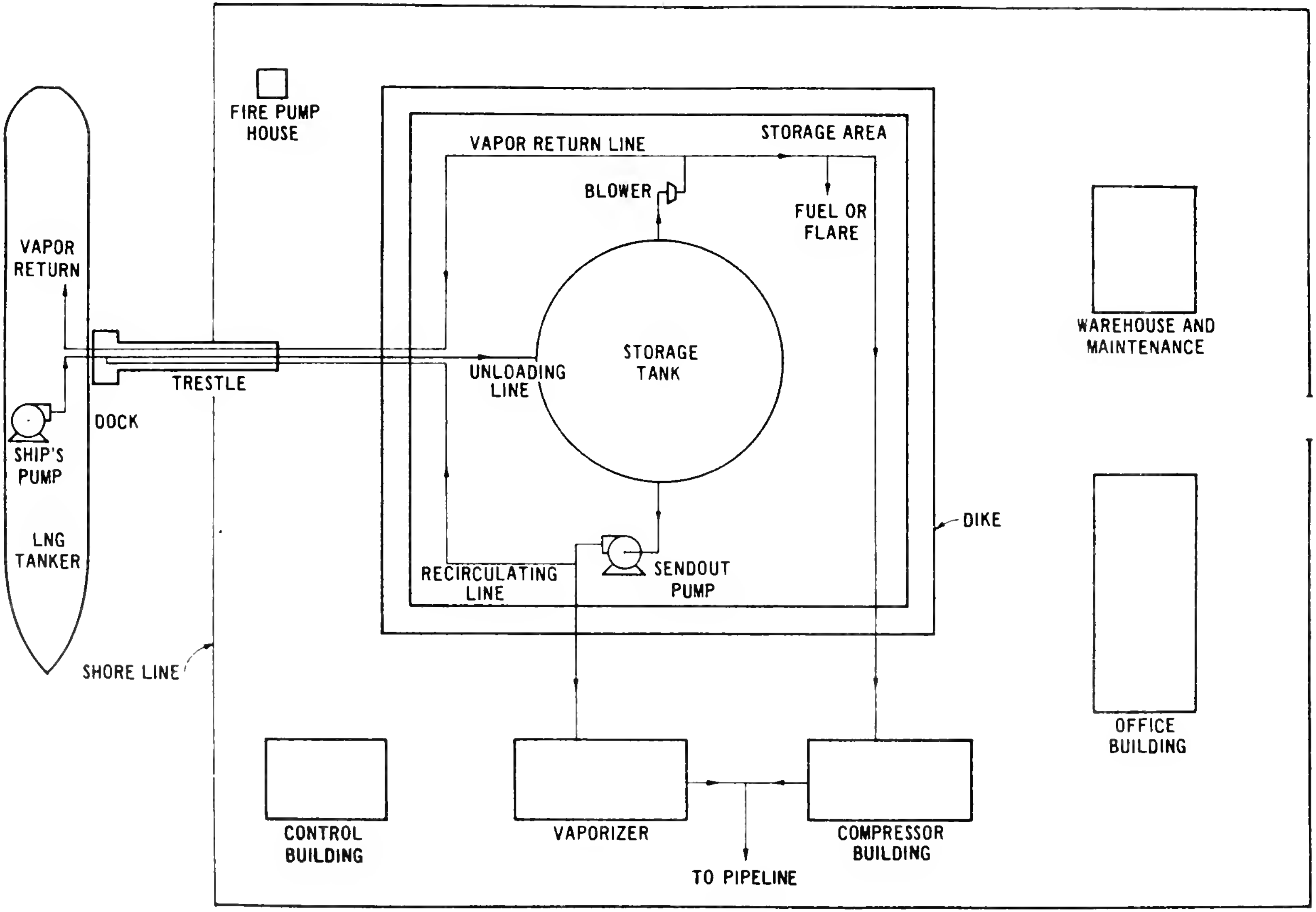
An LNG tanker consists of a series of heavily insulated tanks that are designed specifically to carry LNG. The tanker may be 1,050 feet long with a draft of 38 feet, and a capacity of up to 165,000 cubic meters of LNG, the equivalent of 3.2 billion cubic feet (BCF) of natural gas [9].

A regasification plant essentially reverses the processes that take place at a liquefaction plant. The regasification plant receives LNG from a tanker, heats the LNG in a vaporizer to return it to a gaseous state, and then sends it to the market area in a natural gas pipeline. The two sources of heat available for regasification of LNG are simple heat exchange with seawater, or a gas or oil-fired system either in direct contact with the LNG or through the use of an intermediate fluid such as water or propane [9]. Liquefaction and regasification plants have similar components, including storage tanks, marine terminals, processing areas, pipelines and administrative offices (Figure 7). One proposed LNG regasification plant, at Oxnard, California, will initially be able to produce gas at 522 MCFD, with a maximum potential output of 4 BCFD. An average of one LNG tanker every five days is expected to serve the plant at the initial processing rate.

An important safety consideration that applies to the entire LNG system is that LNG spills create serious major hazards from fire and explosion.

Although small LNG tankers have been unloading at Boston Harbor about once a month since 1971, no major LNG system is in operation to supply the United States market. There is only one liquefaction plant in the United States (Kenai Peninsula in Alaska), and there are none under construction, although an LNG system was considered as one means of bringing Alaskan North Slope gas to the "lower 48." A pipeline through Canada to the mid-west now appears to be the favored plan. Regasification plants have already been built or are nearing completion at Cove Point, Maryland (Chesapeake Bay), Elba Island, Georgia (Savannah River), and Lake Charles, Louisiana. Another regasification plant is proposed for Oxnard, California.

Figure 7. Flow diagram for an LNG receiving terminal (Source: Reference 28).



3.10.2 Siting Requirements

Major siting requirements for LNG regasification plant sites include the availability of a large tract of level land, and access to a marine terminal with a deepwater channel or pipelines for import and export of products.

Because of the high costs of pipeline construction, the large water demand, and the need to keep LNG below its low boiling temperature, regasification and liquefaction plants are normally sited as near the waterfront as possible. The regasification plant also needs to be near a commercial gas transmission line. However, LNG plants may be located as far as two miles inland for environmental or other reasons.

Because of the hazardous nature of LNG, the plants are usually located in rural areas. Plant sizes may range from 200 to more than 1,000 acres, with a substantial portion of the acreage set aside as a buffer zone. For example, the proposed Oxnard, California site consists of 218 acres, 30 acres of which would be initially developed, and a maximum development of 46 acres. For safety reasons, plant processing units would be sited at least one-third mile from neighboring buildings and communities.

Work areas must be level, with soil bearing strength capable of supporting heavy storage tanks. The site also must be geologically stable in order to eliminate the possibility of release of LNG from earthquake-ruptured tanks.

Marine terminals for an LNG system should have sheltered waters (to minimize LNG transfer risks) deep channels, turning basins, berthing space, and easy access to the open ocean. The LNG ship offloading system proposed for Oxnard would use a pipeline on a trestle to connect the dock with onshore storage; the system for Cove Point has its pipeline in a seafloor tunnel. Both systems reduce the need for channel and turning basin improvements.

3.10.3 Potential Sources of Disturbance

LNG plants have a moderately high potential for adverse environmental effects involving deepwater marine terminals and associated long piers, site clearing and grading, onshore pipelines necessary to transport the gas to market, and some aspects of pollution control. The use of adjacent surface water or groundwater in heating or cooling the gas and the integrity of pipeline connections are of particular importance. (Onshore pipelines and marine terminals are discussed in Sections 3.2 and 3.3.) Roadways are a significant siting consideration for LNG plants only during construction when access roads may experience heavy truck traffic and increased volumes of general traffic.

Emissions to the atmosphere may be present in the form of vaporized LNG (i.e., natural gas) produced during transfer and from storage tank vents. Natural gas vapor is commonly used to fill the space over the liquid in LNG ship tanks and storage tanks. LNG vapors may also be used as fuel for vaporizing LNG, flared or compressed, and sent out through the gas transmission lines. An accident that released LNG to the atmosphere could result in catastrophic explosion and fire (see Section 4.19.6).

Subproject: Site Preparation (SP-5)

Disturbing Activity: Clearing, grading

A new LNG plant usually involves a relatively small amount of land for equipment and structures and a large amount for a buffer zone and for future expansion. Though a direct waterfront location is considered advantageous, only the marine terminal and the pipeline to the plant are waterfront-dependent. If an LNG plant site is set well back, land clearing and grading activities may have minimum potential for creating disturbances that affect fish and wildlife, provided that vital areas such as wetlands and endangered species habitats are avoided, watercourses are protected, and erosion control and other precautions are taken. If a plant is located on the waterfront, full scale site preparation and development controls and precautions are required.

Subproject: Site Development (SP-6)

Disturbing Activity: Line constructing, installing

The site development plan for the plant work areas must provide for wastewater disposal systems and underground stormwater collection systems because of the potential for leaks of toxic substances. In addition, utilities, water supply, and other needs, such as storage tank containment dikes capable of handling a complete spill must be provided for in the site development plan.

Subproject: Stormwater Systems (SP-12)

Disturbing Activity: Stormwater conveyance

LNG plant storage tanks, pipelines, and process areas have a potential for leaks and spills that could contaminate stormwater runoff. These areas require berms and other containment systems to handle the maximum expected volume of stormwater runoff. Stormwater runoff collection and treatment systems must also have adequate capacity to handle the maximum anticipated quantities of liquid hydrocarbons and other toxic contaminants.

Subproject: Industrial Wastewater Systems (SP-14)

Disturbing Activity: Wastewater disposal

Hydrocarbon levels in the cooling and process waters in an LNG liquefaction or regasification plant usually increase as the water is utilized. These wastewaters should be treated as appropriate for specific LNG plants following EPA requirements.

Subproject: Industrial Cooling Water Systems (SP-15)

Disturbing Activity: Circulation of cooling (heating) water

A water cooling system for an LNG liquefaction plant or a gas-fired LNG vaporization process may be a once-through or a recirculating system. Water demands for cooling depend on the plant capacity, and the type of cooling system used. A combination air and water closed cycle cooling system would minimize water demands. The temperature of the water passing through the plant rises significantly in some cooling processes and types of plants. Chemicals added to the cooling water as biocides and to reduce corrosion in the system, such as hypochlorite, are highly toxic and require collection and treatment prior to release.

The cooling operations of LNG liquefaction plants need large amounts of water. The 3 BCFD liquefaction plant proposed for Alaska would require more than 1 million gallons of cooling seawater per minute [29] and a 1 BCFD capacity regasification plant would need 140,000 gallons of heating water per minute [30]. At the regasification plant, the estimated drop in water temperature would be "70°F between inlet and outlet" [16]. It is highly unlikely that these enormous water volumes could be supplied by groundwater. Seawater would probably be used for all but boiler water and domestic needs. When withdrawing groundwater for these uses, precautions must be taken to avoid environmental disturbances, such as saltwater intrusion and land subsidence.

PART 4 - POTENTIAL DISTURBANCES OF STANDARD SUBPROJECTS

This part reviews the major construction and operation activities associated with OCS-related projects and describes the ecological disturbances that arise from them. The material is presented under 20 standard subprojects, which are the basic engineering work units involved in implementing the variety of OCS-related projects described in Part 3. In addition to the effects of primary OCS facility development, the subprojects cover a wide range of effects on coastal communities from secondary development ranging from roadways, to beach protection, to mosquito control. Specific sources of the material for the subprojects are cited in the text except for that which came from The Conservation Foundation's guidebook Coastal Ecosystem Management (John Wiley and Sons Interscience, New York, 1977) [61].

4.1 NAVIGATION IMPROVEMENT - SUBPROJECT 1

Marine navigation improvement, as treated here, applies to existing navigable waters of the United States, and includes: the widening, deepening, or straightening of natural channels; the excavation of new channels in navigable areas; and other improvements (such as navigation aids). Navigation improvement is a major subproject of many onshore OCS facilities projects, involving navigation channels, turning basins, berthing spaces, harbors, canals, and marinas. It does not encompass excavation of waterways in presently non-navigable areas (i.e., canals cut through the lands) or those dug primarily for real estate development (see Subproject 7, Artificial Waterways).

4.1.1 Summary

Most navigation improvement work is done with marine dredges. The dredged material, or dredge spoil, is barged or piped to a disposal area or, infrequently, temporarily stored aboard for later disposal. Navigation improvement projects range from a few cubic yards, excavated by dragline, to a long deep channel producing millions of cubic yards of spoil, excavated by ocean-going hopper dredges. Considerable differences are imposed by type of equipment as well as scale and season of the work.

Plans for new navigation projects should recognize the potential need for periodic maintenance dredging (throughout the project life) after completion of the initial work on the project. In many cases the requirement of maintenance dredging will place a limit on the feasibility of the original project, because of the expense or difficulty anticipated in locating adequate spoil disposal areas.

The major activities associated with a navigation improvement project are dredge operations and spoil disposal. A variety of ecological disturbances may be associated with dredging and spoil disposal within coastal water basins. Habitat alteration has particularly high potential for generating damage to coastal ecosystems and reducing biotic carrying capacity. Major potential ecological effects include: (1) increased turbidity, (2) sediment buildup, (3) reduction of oxygen content, (4) disruption and alteration of especially productive estuarine bottoms and their biota, (5) creation of stagnant deepwater areas, (6) disruption of estuarine circulation and (7) increased upstream intrusion of salt water and sediments.

4.1.2 Dredging

Adverse effects usually can be reduced by the proper choices of location and design of the channel, channel alignment, minimum depth and width dimensions, construction equipment, disposal of spoil, and performance controls on dredges (e.g., silt curtains, choice of season).

Alignment: The general location of the navigation improvement is usually dictated by selection of the onshore site. Nevertheless, there is considerable opportunity for adjusting the channel alignment to avoid vital habitats and to limit new dredging by using existing natural estuarine channels. This will reduce one of the adverse effects of channel dredging--the direct removal of vital habitat areas. The identification of all vital habitat areas in the water body, therefore, should be done before final channel alignments are decided. Vital areas should not only be avoided but buffer strips around them should be assured.

Channels dredged too close to the shore in shallow-water areas may result in severe shoreline recession, both from channel slumping and from direct erosion of banks. The presence of a channel may increase the frequency and speed of boat passage thereby increasing the intensity of boat wake and shoreline erosion. In addition, the deepening of the shoreline will decrease the dissipation effect that shallower water bottoms have on incoming waves.

A major environmental effect associated with dredging in shallow-water areas is disruption of water circulation patterns. The effects are particularly severe when channel cuts are made across low marshes in an attempt to straighten winding creeks and rivers. A common effect is sedimentation of cut-off "oxbows".

Saltwater intrusion can be caused by dredging channels up shallow tributary rivers or into wetlands (shorelands dredging is discussed in Subproject 7). The resulting chemical and physical changes in the water and alteration of circulation patterns may unbalance the ecosystem. Such effects can be avoided by using natural channels and by minimizing channel depths.

Dimensions: Normally, the deeper and wider a channel is dredged, the greater are the ecological effects, particularly in shallow waters. Channels dredged into shallow-water areas should be limited to the minimum depth needed for the majority of watercraft which will use the area on a sustained basis. This practice lowers the amount and cost of initial dredging and decreases the frequency of maintenance dredging operations.

Adverse effects are associated with the creation of areas too deep to permit the light penetration necessary to sustain a balanced aquatic habitat. Conversely, too shallow a depth causes excess turbidity, caused by resuspension of silt by the prop wash from passing boats.

Adverse effects can be reduced by minimizing the length, width, and depth of the channels. In general, a navigation channel width should not exceed three or four times the width of the largest vessel for which it is designed. Similarly, operable depth should not exceed 3 feet (0.9 meter) deeper than the deepest draft vessel at low water. Additional depth may be considered for newly dredged channels to accommodate siltation or slumping, reducing shoaling and therefore, the frequency of maintenance dredging.

Deep harbor entrance channels may increase the inward flow of salt water, accelerate sedimentation, and increase the inward transport of materials from down harbor or from the ocean, as exemplified by the problems of Savannah Harbor (Georgia) where channel deepening resulted in increasing deposits of ocean source sediment [31].

Additional problems are created by imbalances in water circulation resulting from major channel deepening, as demonstrated in the Sacramento River delta project which would have greatly increased the subsurface flow of salt water resulting in saltwater intrusion. Such a change could shift and disrupt the salinity-dependent nursery areas of striped bass and other important species and have other complex effects.

Depressions or "deep holes", resulting in long-term changes in currents and water circulation, may affect mixing and flushing of estuarine waters, eventually causing changes in water temperature, salinity, dissolved oxygen, sediment accumulation, and ultimately low net productivity [32]. Dredge holes may accumulate anaerobic sediments and pollutants which may leach into nearby water systems [32]. Level-grade dredging and avoidance of channels deeper than the harbor sill depths reduce these impacts on estuarine resources.

The effects of channel edge slumping on the residual slope of the channel sides will be a function of the sediment particle size and roughness, local current velocities, and other factors. To avoid excessive slumping and therefore the high expense of maintenance dredging, channel sides should be initially dredged to a stable slope (or final "angle of repose") during the initial operation, the exact cut depending on specific geohydrological conditions. Excessively steep channel edges may lead to unnecessary loss of adjacent vital habitat areas, such as shellfish or grass beds.

Dredge Type: Dredges are classified as mechanical types or hydraulic types (Table 21, Figure 8). A third type, the "suction/mechanical" dredge, is a variation on the hydraulic dredge which has a cutterhead or rotating bit attached to the mouth of the suction line to loosen compacted sediments and rock.

A major functional difference between mechanical and hydraulic dredging is the amount of water contained in the dredged material. Mechanical dredges collect bottom material at or near the saturation level of the submerged soil, while hydraulic dredges add water to facilitate transportation of the dredged material. Water is added to create a slurry which can be pumped to the disposal area. The size of particles of materials being dredged and the distance being pumped govern the amount of water used to create the slurry. Disposal of the slurry mixture causes particles to settle according to grain size, whereas mechanical dredging has no arrangement of particle types. The use of hydraulic dredges can greatly speed up the dredging process as larger quantities of material can be moved in a shorter period of time compared to mechanical dredges. Suction dredging, suitable only for removal of loose material, produces the least turbidity of all dredging activities, if properly operated [31]. However, the suction dredge has a high potential for ecologic disturbance at the terminus of the effluent pipeline, where the spoil (a slurry of usually about 20 percent sediment and 80 percent water) is discharged. The effects may be severe if the spoil contains a high proportion of contaminants: organic matter, nutrients, toxics, heavy metals, and fine sediments. Impacts are reduced if spoil areas are diked to confine and settle the slurry material.

The mechanical dredge is less desirable from an environmental point of view because material is washed freely from the bucket as it is raised from the bottom. This increases turbidity, which can in turn reduce dissolved oxygen, release toxic chemicals, reduce light penetration, clog the gill structures of organisms, and destroy microorganisms usually in the immediate project vicinity. The material moved must be disposed of within the length of the dredge boom

Table 21. Five Common Types of Dredge Rigs
(Source: Reference 33)

" Dipper Dredge—The dipper dredge is basically a power shovel mounted on a barge. the barge (which serves as the work platform for the shovel) uses three spuds (two spuds at the forward end and a single spud at the stern) to provide stability during dredging operations. The dipper dredge is capable of excavating from 3 to 10 cubic yards of hard material per cycle. It can remove blasted rock or loose boulders. The dredged material is discharged within the reach of the dipper boom. The digging boom limits the depth of excavation to not more than 60 feet.

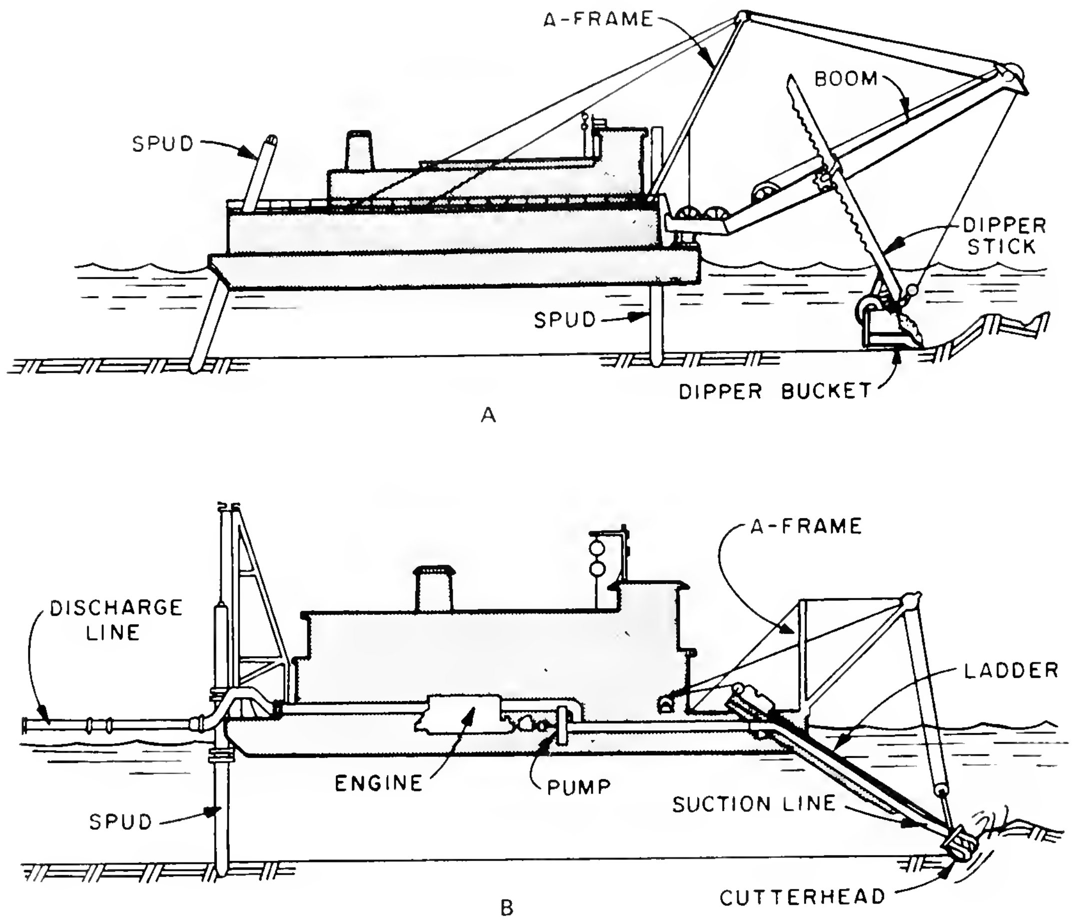
Ladder Dredge—The ladder dredge uses an endless chain of buckets for excavation. The dredge is mounted on a barge which is stabilized by side cables during the dredging operation. The ladder dredge is capable of excavating from 1 to 2 cubic yards of hard material per bucket. It can remove blasted rock or loose boulders. The excavated material is dumped from the buckets into chutes or onto belts and is discharged over the side of the barge. The design of the ladder limits the depth of excavation to not more than 100 feet.

Bucket Dredge—The bucket dredge is basically a crane mounted on a barge. The bucket (clamshell, orange-peel, or dragline) can be changed to suit the job conditions and material to be removed. The barge (which serves as the work platform for the crane) uses either spuds or anchor lines to provide stability during dredging operations. The bucket dredge is capable of excavating moderately stiff material in confined areas. It is generally not used for large scale projects. The excavated material is dumped within the reach of the boom.

Pipeline Dredge—The pipeline dredge is the most versatile and widely used dredge. It can handle large volumes of material in an economical fashion. Using a cutterhead the dredge can excavate material ranging from light silts to heavy rock. It can pump the dredged material through floating and shore discharge lines to remote disposal areas. Pipeline dredges range in sizes (as measured by the diameter of the pump discharge) from 6 inches to 36 inches. The depth of excavation is limited to 60 feet. The rate of dredging will decrease with (1) difficulty in digging, (2) increase in length of discharge pipe and (3) increase in lift to discharge elevation.

Hopper Dredge—The hopper dredge is a self-propelled vessel designed to dredge material hydraulically, to load and retain dredge spoil in hoppers, and then to haul the spoil to a disposal area or dump. Loading is accomplished by sucking the bottom material through a drag-head into the hoppers while making a cut through the dredging area. The quantity of volume pumped during a loading operation depends primarily upon the character of the material and the amount of pumping time involved as well as the hopper capacity and the pumping and propulsive capability of the dredge. The loaded dredge proceeds to the disposal area where the dredge spoil is discharged through gates in the bottom of the hoppers."

Figure 8. Examples of types of dredges: (A) bucket or mechanical dredge, and (B) suction or hydraulic dredge (Source Reference 33).

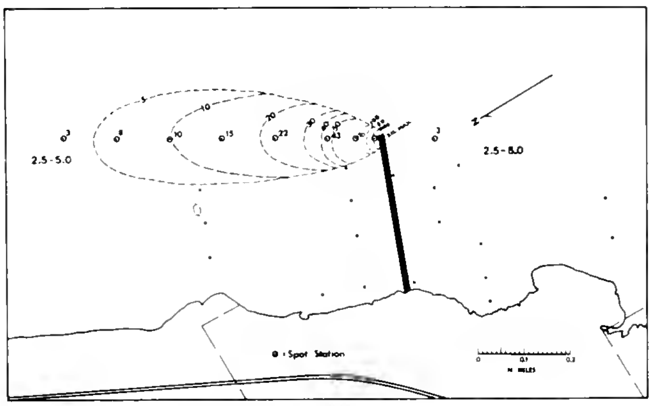


or temporarily stockpiled on barges or trucks and moved to a disposal area. Mechanical dredges are less expensive to operate, do not require pipelines and are more versatile, being designed to cut into compacted sediments better than suction dredges [34].

The cutterhead dredge is perhaps the most versatile of all but expensive to operate [35]. It has a high potential for creating adverse environmental effects because of the turbidity clouds that are typically generated in the vicinity of the cutterhead.

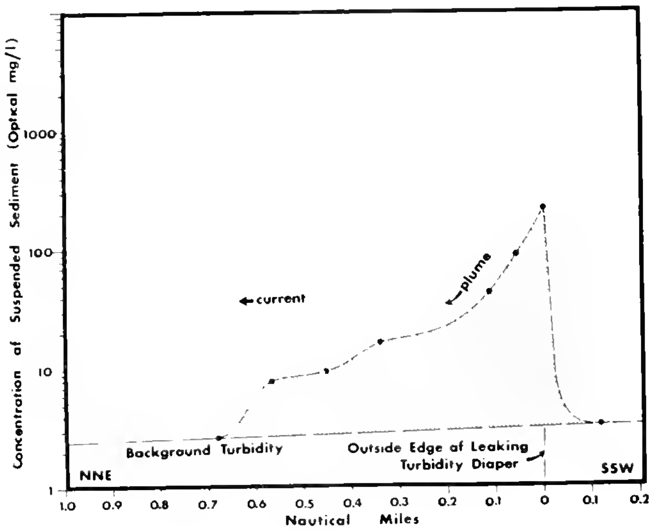
Spillover effects: Proper management of dredging operations is aimed at controlling effects from reintroduction of dredged materials into the water column and the possible release of polluted bottom sediments. Problems associated with dredging are increased water turbidity and the release of large quantities of trapped nutrients, organic materials, and toxic pollutants. The turbidity plume from released material will usually form a visible, elliptical pattern from the dredge or dumping site, as shown in Figure 9.

Figure 9. Example of a "fugitive" dredge plume with a protective turbidity diaper in place (Source: Reference 36).



The above conditions are usually temporary, lasting for the period of dredging and a few days after its completion; however, the environmental effects created during the work periods can be of sufficient magnitude to require that steps be taken to eliminate or control their extent. Included in the short-term effects that may be expected are: clogging of gills of aquatic organisms with silt; reduced light penetration; increased release of nutrients; depletion of dissolved oxygen; and resuspension and possible uptake by organisms of heavy metals, pesticides, or other toxic substances. In an attempt to contain turbid water near the dredge site, preventive "silt curtains" or "diapers" have been developed. These floating vertical barriers have been used around both dredging and spoil disposal operations with varying success, since they cease to function in moderate to high velocity currents or in cases where there is wave action from wind or boat traffic (Figure 10).

Figure 10. Concentration of suspended sediments in a plume caused by dredging (Source: Reference 37).



Schedule: Dredging may be more adverse at one time of the year than another. Dredging operations along migration routes of fish and other marine animals might be suspended near known nursery areas during periods when the young of a species are passing through critical development stages. Turbidity and poor water quality created by dredging operations usually have a more significant impact on larval and juvenile populations. Timing for dredging restrictions must be developed by knowing the life cycles of the critical species of the ecosystem involved.

4.1.3 Spoil Disposal

Spoil is the common term for sediments and other material excavated by dredging a navigation channel. Its disposal may cause economic and environmental problems. In some cases, spoil becomes a resource for shoreline landfill or for mining of aggregate sand and gravel for concrete. Environmental considerations have fostered a new trend away from casual open-water disposal and toward highly engineered land and contained disposal [31].

Open-water disposal: Ecological damage may occur when dredge spoil is dumped directly overboard to spread through estuarine waters. Short-term effects may include increased turbidity, sediment buildup, oxygen depletion, and the release of nutrients and possibly toxic pollutants. Long-term effects include changes in water circulation, accumulation of deposits on estuarine bottoms that may prevent recolonization by benthic species, and subsequent resuspension of polluting substances by boats, wind, and currents.

Altered by long uninterrupted spoil banks, large portions of estuarine areas can become isolated or removed as productive units from the total system [32]. Extensive damage to fish and wildlife resources can occur when dredge spoil is deposited on vital habitats such as wetlands, tide-lands, or shellfish beds. Before disposal sites are chosen, an inventory should be taken of all vital habitat areas, and these areas should be excluded from consideration as disposal sites.

When the dredge spoil is coarse and clean--consisting of sand or gravel--overboard disposal may be acceptable, provided that the spoils do not contain toxic pollutants and are not deposited in ridges that significantly impede water flow.

Ocean disposal: A disposal alternative that may be used to protect estuarine ecosystems involves transport of spoil to the ocean by hopper dredge barge, or possibly pipeline. There are important differences in opinion as to the environmental impact of deepwater ocean disposal of various types of waste. In regard to dredged materials, it appears that ocean disposal is acceptable for all but the most polluted spoil, if the site is sufficiently far offshore to ensure against currents carrying the spoil back onto the beaches or into the estuaries. Ocean disposal is presently limited by the scarcity of hopper dredges as well as the high cost of transport.

Land disposal: Spoil disposal on land offers the possibility of preventing many of the adverse environmental impacts that occur with open-water disposal. Disposal areas are located inland, as far away from the water's edge as possible and in places where their presence will not interfere with vital habitat areas (e.g., in no instance should wetlands be used). Upland disposal areas are usually limited to within one mile of the water's edge. Upland disposal is not without concern. Items of evaluation include (1) the quality of the water effluent separated from the spoil, (2) the potential loss of wildlife habitat used as a disposal site, and (3) possible alterations to the natural drainage pattern of wetland or upland areas used for disposal and (4) pollution of ground-water aquifers. Dredge spoil may be very loose material and may require a number of years of drying before the land can be reused. This often makes available upland areas hard to find. Approximately 1600 cubic yards of dredge spoil occupy an acre to a depth of one foot.

The land area required for spoil disposal is often extensive and the problems of site acquisition for land disposal are difficult nationwide. In urban situations the only available sites with sufficient acreage may be those that are assigned to open space recreation, or other natural areas. Because of disadvantages in land characteristics, spoil volumes, land use, and other factors the shortage is reported to be most acute in the southeastern United States [31].

Placing disposal areas on impermeable soil (such as clay) behind leak-proof dikes, directing wastewater return weirs to saltwater habitats and other methods are used to reduce impacts from this spoil method.

<u>Contained Disposal</u>: Despite the high cost of dikes and water control structures, disposal of spoil in containment areas in or at the edge of estuaries is a common proposal. Containments range in size from less than 10 acres to over 4 square miles and have life expectancies from less than 1 year to over 100 years [31]. Nearly all containment areas are enclosed by tight dikes and equipped with height-adjustable spillways to accommodate varying filling rates. Containment areas include a detention capability for the removal of suspended matter by settlement [38]. Although the effluent is somewhat improved before it flows over the spillways, a higher level of treatment is often required before discharge when polluted spoil is involved. From Table 22, it is possible to compute flows from pipelines of various sizes and therefore to determine the required size of the detention facility.

Experience has shown that polluted fine sediments (fines) accumulate on the surface of the spoil mass in containment areas, particularly where maintenance dredging spoils are deposited. To prevent fine material from washing back to the estuary with runoff from rainstorms, it is necessary to keep the spillways (stop logs, return weirs, etc.) in place and functioning after the dredging has terminated or else to cover the areas with a layer of clean, coarse fill [40].

Retaining dikes are primarily earth embankments; however, open-water containment facilities have also been constructed, and in certain cases rockfill or slag has been used. Dike characteristics are largely dependent upon foundation conditions and available construction materials. Construction may be difficult because of generally poor organic foundation conditions or the use of low-quality borrow materials. Retaining dikes often require continual maintenance. Foundation and material deficiency failures have occurred largely because of inadequate dike design, poor construction practices, and minimal inspection of dikes during dredging operations. The effects of seepage are directly responsible for or contribute to the majority of retaining dike failures [41].

Table 22. Discharge Rates for Hydraulic Dredge Pipelines (Source: Reference 39)

Pipeline Diameter (in)	Discharge Rate (for Flow Velocity of 12 ft/sec)[a] (cu ft/sec)	(gal/min)
8	4.2	1,880
10	6.5	2,910
12	9.4	4,220
14	12.8	5,750
16	16.5	7,400
18	21.2	9,510
20	26.2	11,740
24	37.7	16,890
27	47.6	21,300
28	51.3	23,000
30	58.9	26,400
36	84.9	38,000

[a]To obtain discharge rates for other velocities multiply the discharge rate in this table by the velocity (ft/sec) and divide by 12.

Use of Existing Areas: Many old spoil banks remain in coastal areas. These spoil areas have caused considerable damage in the past but now the material has compacted or eroded away. Further spoil disposal in these areas should not significantly increase the loss of vital habitats; however, harmful impacts from new dredging should be kept to a minimum.

Polluted Spoil: Disposal of polluted spoil, material containing high concentrations of heavy metals, pesticides or other contaminants susceptible to resuspension when dredged, poses a significant threat to estuarine areas. Consequently, bottom materials to be dredged should be analyzed for the type and content of pollutants. If spoils are found to be polluted they must be handled as prescribed by pollution control agencies. Several methods of treating spoil to remove contaminants and to improve the quality of effluent from dewatering operations at disposal sites are available. Treatment methods include flocculation, filtration, aeration, incineration, chemical processes, and sewage plant treatment. These are all very costly.

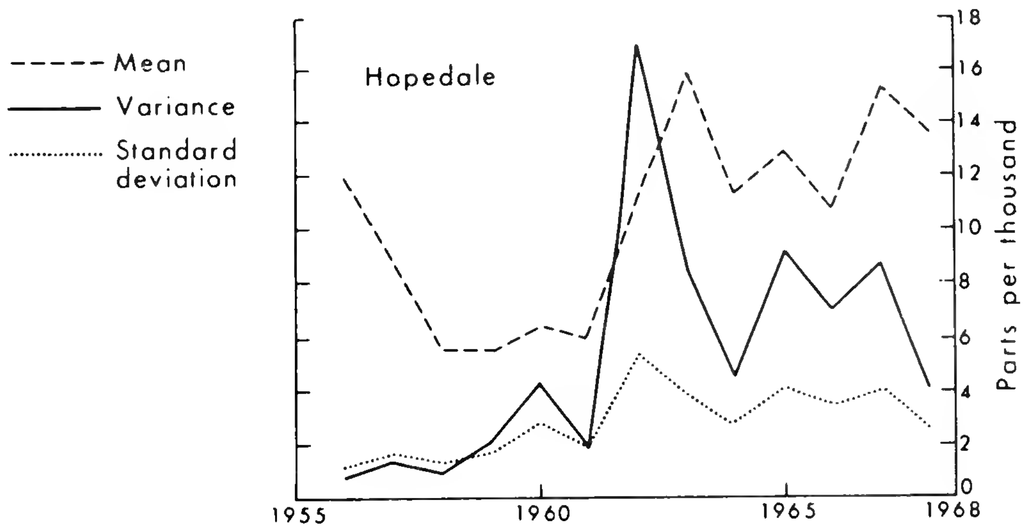
Mitigation: Creation of habitat through disposal of dredge material offers a constructive use of some dredge spoil material. For example, islands of spoil can absorb large volumes of materials and become desirable habitats for shorebirds or utilized to create marshes. If clean, coarse dredge spoil is available (such as coarse sand), islands may become productive intertidal flats [39]. Spoil placement and its effects on hydrology of the system, island erosion and other factors must be evaluated.

Combined Effects: The Mississippi River-Gulf Outlet in coastal Louisiana serves as an example of the combined effects from dredging of navigation channels. Construction of the channel destroyed 23,606 acres of marsh and shallow nursery areas of aquatic life--17,058 acres by spoil deposition and 6,548 acres by deepening. It has greatly altered the hydrology and water chemistry of the adjacent estuarine areas. The large cross-section of area provides an avenue of ingress and egress for runoff and tidal waters. Saltwater intrusion is a major problem. Changes in salinity are well-documented. Recording stations in the vicinity of the channel show significant changes (Figure 11) after the channel was completed in 1962 [42].

Gagliano has summarized negative ecological effects of canal dredging in the Gulf coast region as follows [42]:

- Direct loss of productive habitat through dredging;
- Direct loss and/or reduction in habitat quality through spoil disposal;
- Saltwater intrusion causing faunal and floral changes;
- Increased storm-generated surge;
- Accelerated erosion resulting from increased length of land-water interface;
- Increase in runoff rate resulting in loss of freshwater storage;
- Modification of runoff pattern, often creating fresh water deficient areas;
- Accelerated erosion resulting from increase in tidal prism volume;
- Changes in circulation patterns in bays and sounds;
- Accelerated erosion resulting from boat-generated wash;
- Accelerated erosion along unstable canal banks;
- Alteration and/or disruption of longshore drift of sand;

Figure 11. Salinity records from the Hopedale section of the Mississippi River in Louisiana showing evidence of salt intrusion after completion of the Mississippi River-Gulf Outlet Canal in 1962 (Source: Reference 42).



o Introduction of agricultural, urban, and industrial pollutants;
o Segmentation of natural areas, often resulting in drainage and development in resulting smaller units;
o Destruction of unique natural habitats and environments.

He also mentions the following positive effects:

o Increase in land-water interface;
o Spoil may create new habitats and increase habitat diversity;
o Increased access for sports, recreation, and commercial activities.

4.2 PIERS - SUBPROJECT 2

Piers built for mooring marine craft are of concern if they block water circulation, alter or destroy wetlands, or otherwise adversely alter the natural shoreline. Properly located and designed, however, piers should have minimal effects on fish and wildlife resources.

4.2.1 Summary

Piers are defined as structures that extend into navigable waters for the mooring of watercraft or other purposes and includes fixed docks, wharfs, quays, and similar mooring structures. In relation to OCS primary development, piers are built to service a variety of vessels, including those that carry personnel, equipment, and materials to offshore oil and gas fields, that bring materials (pipe, "drilling mud", etc.) to onshore facilities, and that transport oil or gas. In relation to secondary population growth, piers are built primarily for private recreational craft. Piers may be classified as either "open" piling or column-supported structures, or as "closed" solid-fill structures.

Disturbances to fish and wildlife resources occur when piers are improperly designed or sited, blocking tidal circulation, preempting wetlands, or disrupting the littoral environment. The construction and long-term disturbances from piers may also have adverse effects, such as pollution from miscellaneous discharges and debris and from bottom scour by boat propellers, bow thrusters, and vessel contact with the bottom. Indirectly, piers may induce dredging and spoil disposal to further facilitate navigation. Existing harbors may be utilized or expanded for deepwater facilities to avoid new pier construction in undisturbed fish and wildlife areas.

Recently the Corps of Engineers, with cooperation from FWS, has begun to impose environmental constraints on piers in addition to navigational constraints which were traditionally the issue in permit review [43] [44]. Many states also impose environmental requirements. The thrust of these restrictions is (1) to reduce the potential blockage of water flow and decrease in flushing that would be caused by structures, (2) to minimize their encroachment into coastal water areas, and (3) to eliminate as much dredging as possible.

Location and design of the pier are particularly important factors because they have the strongest influence on the degree to which the pier may block circulation, preempt wetlands, or induce dredging. Once a pier is in place, little can be done except to minimize pollution from boats or dock operations.

4.2.2 Location

A new pier location is usually restricted to a particular area because the shore site has already been chosen for reasons of economy, convenience, or availability. Infrequently, a pier proposal may be rejected because minimum ecological safeguards cannot be met. More often, the location would be shifted within the project area to reduce environmental damage.

The placement of a pier within a site will depend upon a variety of natural and strategic considerations including wave, wind, and current conditions, shore and sea bottom configuration, expected vessel types and traffic, and the shoreside layout and operating plan. To the extent possible, piers should be located in areas that have minimal dredging requirements. Locations should be encouraged where it is feasible to build pile-supported piers out to reach suitably deep water. To eliminate dredging, shallow draft boats may use the landward end of the pier, and the larger boats the deeper-water end.

Properly located piers avoid vital areas such as wetlands, grass beds, shellfish beds, and endangered species habitats. The Corps of Engineers limits the encroachment of piers into coastal waters and wetlands to prevent interference with navigation or vital areas. For example, the Baltimore District Office of the Corps has generally not approved piers that extend within 15 feet of navigation channels and has limited the length of all piers to less than one-third of the width of the watercourse [45]. State and local jurisdictions often require or recommend similar or more restrictive limits.

4.2.3 Design

Solid-fill structures extending into water areas are discouraged in most states, except where winter ice conditions preclude piling-supported structures. Filling and bulkheading that normally accompanies solid-fill piers encroach onto the natural shoreline and are generally considered to have adverse effects on coastal ecosystems. Solid-fill piers displace aquatic habitat, alter water flows, create eddies and turbulent back-waters, and increase localized sedimentation. The use of floating docks or pile-supported piers is strongly encouraged by many agencies [46][47][48]. Pile-supported piers placed over a wetland area should be sufficiently elevated to allow sunlight entering from the sides to sustain the aquatic ecosystem underneath.

4.2.4 Construction

In constructing a pier, care should be taken to prevent pollution of coastal waters by silt and associated contaminants. For example, driving piles is preferred over hydraulic jetting because jetting tends to force silt into the water, which may adversely affect water clarity, reduce dissolved oxygen, and smother bottom organisms. Jetting is especially discouraged in wetlands and nearshore waters where the fineness and the organic content of sediment may be the greatest and where the material is most suspendible and most highly polluting.

Appropriate scheduling of pier construction activities may reduce interference to aquatic organisms during important life phases, particularly migration, spawning, and larval growth stages.

4.2.5 Accumulated and Indirect Effects

A dense accumulation of individual piers can cause a major obstruction of water flow along the shoreline, as well as significantly litter and pollute the water (e.g., leaks or spills of oil and gasoline) or restrict water area use for fishing and recreational boating. Authorities commonly discourage the proliferation of private piers by encouraging communities to build neighborhood boat landing facilities. The potential effects of boat operation on coastal ecosystems (e.g., pollution, stirring up the bottom) should also be considered in reviewing plans for piers and docks, particularly in relation to boating density, depth of waterway, condition of bottom, and currents and flushing rate of basin. Many waterways are reaching their capacity to handle boat traffic. Individual permits should be reviewed in relation to expected cumulative effects.

4.3 BULKHEADS - SUBPROJECT 3

Bulkheads built in the coastal zone have a high potential for adverse effects on fish and wildlife and their habitats. If not properly located and designed they eliminate valuable wetlands and vital areas, adversely alter the shoreline through scouring and change in water flow, interfere with runoff, and cause general ecological degradation of the land-water interface. Bulkheads are used extensively along industrial waterfronts, such as those developed with OCS-related onshore facilities.

4.3.1 Summary

A bulkhead is a vertical wall of wood, steel, or concrete, built parallel to the shoreline and designed to reflect waves and control erosion. Bulkheads referred to here are the structures usually placed in protected waters in the intertidal zone; their counterparts on the open seacoast are usually termed seawalls. In relation to OCS primary development, bulkheads are usually built to provide boat docking capabilities for loading and unloading of heavy materials or to hold fill deposited to convert wetlands and low-lying shoreland to industrial sites. In relation to OCS secondary development these structures are built to extend land, to protect the shoreline from erosion, provide boat docking convenience, or serve aesthetic purposes.

Major environmental objections to bulkheading arise from the loss of coastal marsh and other vital habitat areas, the reduction in size of water bodies, the accompanying water pollution, and the interruption of the movement of fresh water into the estuary. The adverse impact is greatest when the outer periphery of a coastal marsh is bulkheaded and then covered with dredge spoil from the bay bottom or upland fill material in order to extend property lines.

The proliferation of bulkheads along the shores of an estuary results in massive ecologic degradation and a serious reduction in carrying capacity. Any one of the numerous small bulkheads may have a lesser effect when looking at an entire coastline but the accumulation of bulkheads may eliminate a high proportion of the total wetlands and natural shoreline segments.

Riprap or stone protection is often the easiest and least costly technique for shoreline protection. This advantage is augmented by the high permeability of riprap and its other ecological advantages.

Although details may vary from case to case the principles concerning shore and bank protection are relatively few and simple. Whenever possible the existing shoreline should be preserved with natural erosion protection measures such as planted marsh grasses, rather than structures. Bulkheads should not disrupt the outward flow of groundwater or runoff nor intrude into wetlands or other vital habitat areas.

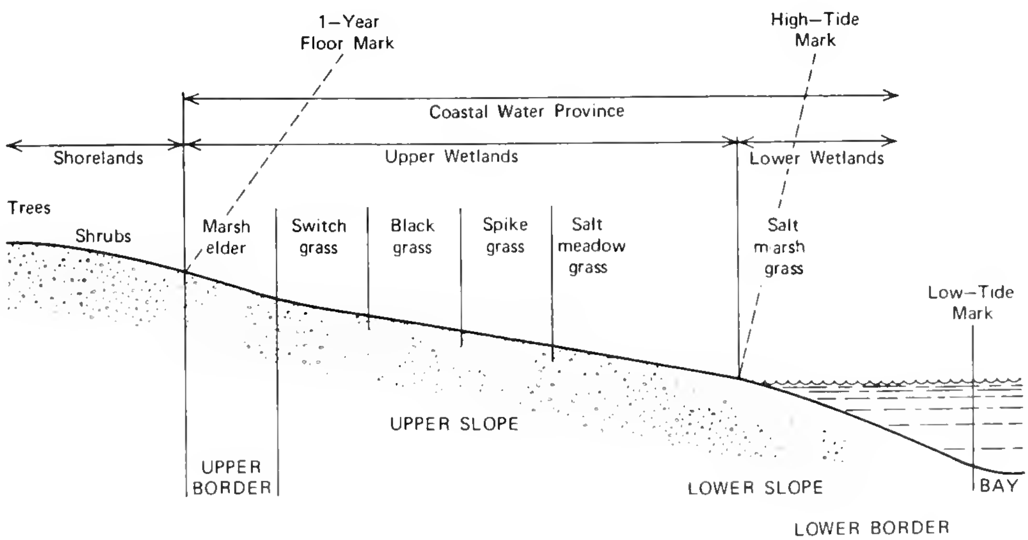
4.3.2 Location

The location of a bulkhead is restricted to the particular site already chosen for the overall project. However, placement can be shifted within the project site to the most favorable situation, design remedies made as a condition to the approval, or a new project design devised which eliminates the need for bulkheading.

When properly located, bulkheads will avoid any vital areas, including wetlands, endangered species habitats, etc. Also, bulkheads should be located a sufficient distance from vital areas because of the threat of adverse disturbances from bulkhead placements such as the introduction of resuspended sediments from wave reflections off the structure or anaerobic conditions from disrupted water circulation.

There are a number of reasons to require that bulkheads be built above the annual flood mark. By definition coastal wetlands that should remain undisturbed lie below this level (see Figure 12). In addition,

Figure 12. Typical New England coastal wetlands with the one-year or annual flood line (Source: Adapted from Reference 49).



bulkheads that extend into water areas often adversely alter water circulation, increase scouring of the bottom, reduce the surface area of the estuary, and preempt such vital habitat areas as tideflats and shellfish beds, in addition to marshes.

An exception to the requirement of building bulkheads behind the annual flood line may be justified for bare shorelines, ones that have not supported vegetation and cannot do so in the future. Erosion is typically severe on such shorelines, and stabilization is often clearly needed.

Once a bulkhead is in place there is very little that can be accomplished toward minimizing its impacts with the exception of placing stone riprap in front of the structure. Therefore details of design and placement must be worked out suitably before construction starts. In the case of major facilities associated with OCS operation the choice of allowing bulkheads to extend into shallow waters must be weighed against possible dredging required to get navigation up to the bulkhead at a more landward location. These should be reviewed on a case-by-case basis.

4.3.3 Design

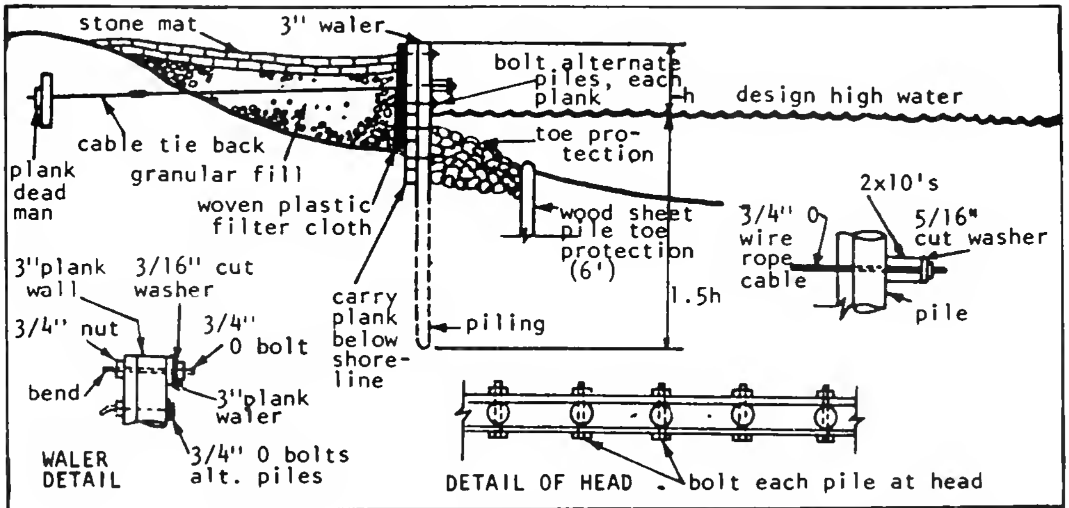
Bulkheads vary greatly in detail of construction and the variety of design and location. These structures may be constructed of wooden piles and planks (Figure 13), interlocking sheet steel (Figure 14), or concrete slabs. Rock riprap structures are also included in this discussion of bulkheads, intertidal shoreline protection devices.

A design feature of value is perforation ("weepholes") of the bulkhead to permit the natural flow of groundwater and runoff to pass through the structure. This release of fresh water provides wetlands with waterborne nutrients and allows the land above the bulkhead to drain. This design also releases hydrostatic pressure from the groundwater head which if allowed to accumulate will cause structural collapse. When an area is exposed to moderate wave energies, riprap with a filter-cloth backing is ecologically more desirable because of its permeability than a vertical bulkhead. The submerged section provides a greater surface area for the attachment of algae, barnacles, and other animals than found on the less biologically productive smooth, flat surface of a vertical bulkhead. Riprap can easily be built to conform to the natural configuration of the shoreline. Riprap structures are less expensive than concrete and are often comparable in price to wooden bulkheads. Riprap structures are usually built on a 2:1 slope and have extended lifetimes. They are constructed with the toe below the mean low-water line (Figure 15).

4.3.4 Construction

In large-scale construction, driven pilings are preferred to jetted pilings as bulkhead supports. Jetting tends to force greater volumes of silt into the water that may lead to turbidity, lowered dissolved oxygen,

Figure 13. Design details of a typical wood sheet bulkhead (Source: Reference 50).



Description	Design depth of water 50' offshore (ft.)		
	3 - 4	5 - 6	7 - 8
Dimensions			
Height (ft.)	5	8	10
Diameter of Piles (in.)	6	8	10
Pile Length (ft.)	13	20	25
Wall plank thickness (in.)	3	3	3
Toe protection wt (lbs.)	70	140	200
List of Materials (per ft.)			
Piling	5.3	8.0	9.3
Waler	1	1	1
Wall Plank (s.f.)	6	9	11
Filter Blanket (s.f.)	9	12	16
Toe Stone (c.y.)	.33	.7	.95
Fill Material (c.y.)	.9	2.0	3.0
Cost $/lin.ft.	60	80	120

and smothering of bottom organisms. Any accompanying shoreline, tidelands or estuarine excavation should be minimized. Turbidity curtains (silt curtains or diapers) should be placed so as to minimize siltation in adjacent waters. Appropriate scheduling of bulkhead construction activities can reduce any potential interference to aquatic organisms during migration, spawning, and other important life phases.

Figure 14. Typical steel sheet piling bulkhead (Source: Reference 51).

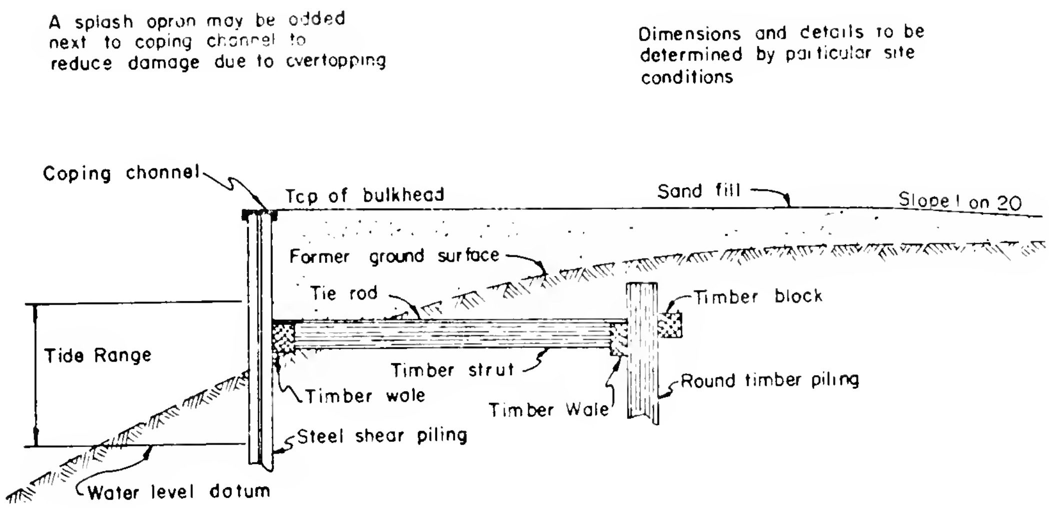
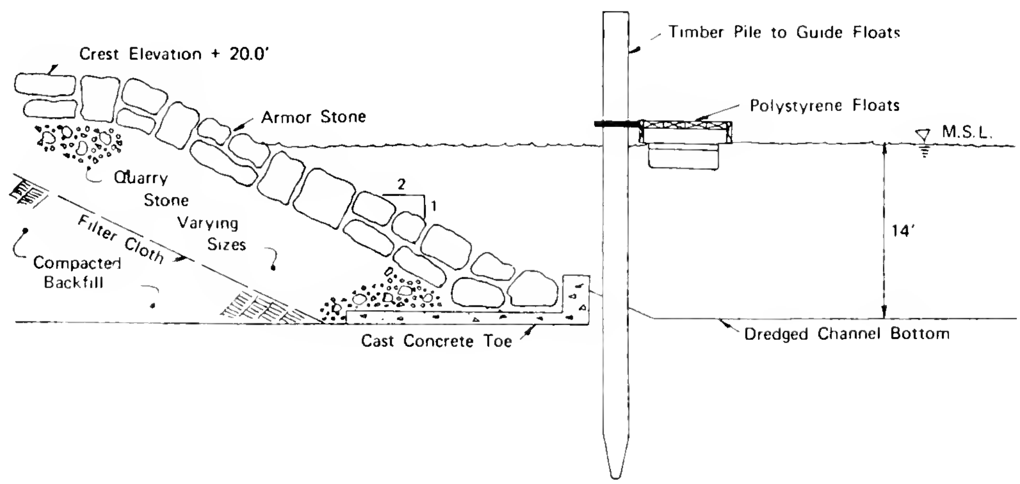


Figure 15. Cross-section of riprap structure and floating dock (Source: Reference 52).



4.3.5 Alternatives

As alternatives to bulkheading for erosion control purposes, eroded shores and banks can often be stabilized by grading the shoreline and planting salt-marsh grasses, mangroves, or other vegetation. Such an artificial marsh barrier is preferable to other types of shore erosion structures where feasible and may prove to be the least expensive. In protected water bodies where erosion rates and wave action are low, an artificial marsh may be an effective method of shoreline protection, since wave forces are absorbed and sediments are trapped by the planted vegetation. It has the added benefit of creating a more biologically productive shoreline, as well as one with higher natural aesthetic appeal. In Florida, mangrove species lend themselves well to shoreline protection [53] [54] as does cordgrass species (Spartina) in temperate zones.

4.4 BEACH STABILIZATION - SUBPROJECT 4

The risks attached to development on the ocean beachfront encourage the building of protective structures to stabilize and safeguard beachfront facilities. Experience shows that these structures may serve only a temporary purpose and provide a false sense of security, therefore, nonstructural programs, such as building setbacks, are now more often proposed.

The incentive to place major OCS facilities on the open beach is small because most of them require protected shorefronts of coastal bays. Nevertheless, the subject of beach protection is so important that it needs to be considered in relation to even so minor an activity as a pipeline crossing and secondary development which may result from OCS.

4.4.1 Summary

Beaches and dunes shift with changes in the balance between the erosive forces of storm winds and waves, on the one hand, and the restorative powers of tides and currents, on the other. The natural beachfront exists in a state of dynamic tension, continually shifting in response to waves, winds, and tide and continually adjusting toward a point of equilibrium (Figure 16).

These natural forces at work at the beachfront are immense, and the power of man to hold the beach at a higher than natural angle of repose (slope) to protect property is limited. Long-term stability is gained by holding the slope or profile intact through balancing the sand reserves held in various storage elements--dune, berm, offshore bar, and so forth (Figure 17). Each component of the beach profile is capable of receiving, storing, and yielding sand, depending on which of several constantly changing forces is dominant at the moment. Stability is fostered by maintaining the storage capacity of each of the components at the highest level.

Figure 16. Standard beach profile--description and nomenclature (Source: Reference 51).

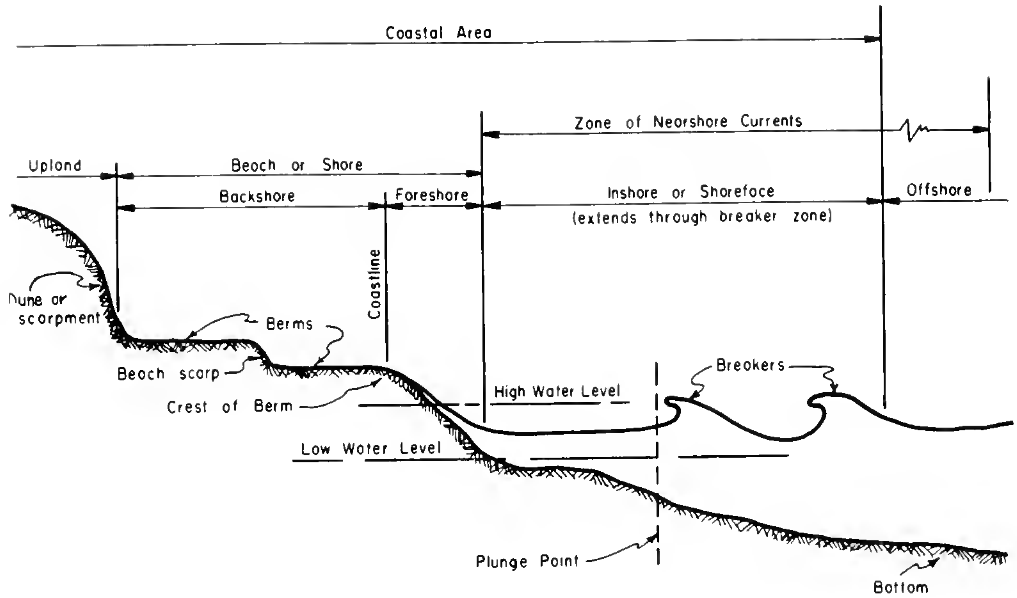
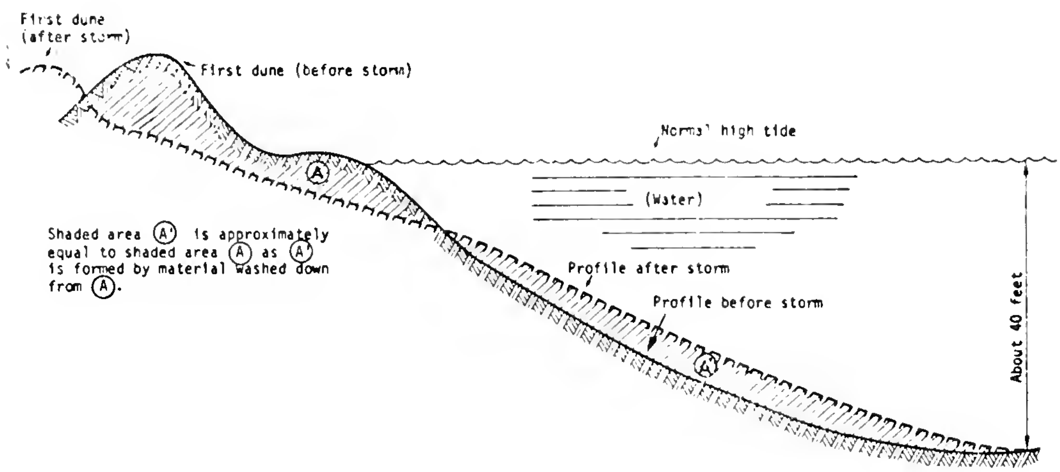


Figure 17. Changes in a beachfront profile caused by storms (Source: Reference 55).



When storm waves carry away a beach, they are taking sand out of storage. In the optimum natural state there is enough sand storage capacity in the berm or dune to replace the sand lost from the beach to storms. Consequently, the effects are usually temporary, with the dune or berm gradually building up again.

The potential processes and activities that disturb the equilibrium of a beach can be classified as either natural or man-made. Natural causes are conveniently grouped according to their time scales [56].

1. Short-term (measured in hours or days). Individual storms can often be the predominant natural factor in determining the condition of a beach, especially in the northeastern United States [57].

2. Intermediate-term (months). Seasonal variations in wave energy can produce significant alterations to beach equilibrium, especially on the United States Pacific coast. The different beach conditions are often referred to as the "summer" and "winter" beach profiles, the former being the result of the lower, shorter waves typical of summer conditions, while the latter are produced by the higher, longer waves of the winter season [58].

3. Long-term (years or decades). Fluctuations in mean sea level over periods of only a few years have been blamed for some long-term alterations of beach equilibrium. Similarly, the slow but definite rearrangement of bottom sediments by storm waves and tidal currents can alter bathymetry to the extent that significant changes occur in the behavior of waves approaching the shoreline [59].

Man-made disturbances to beach equilibrium are usually the result of construction activity within the coastal zone; however, the equilibrium of some beaches is so delicate that it can be upset just by heavy usage for recreational purposes (e.g., by dune buggies and other vehicles [56].

In all these examples, whether natural or man-made, a disruption to beach equilibrium will occur if one or more of the three elements essential to the preservation of that equilibrium is altered. The disruption will generally occur in the following way(s) [56]:

1. The supply of beach material (sand) is altered. If the supply is reduced, the beach can respond only by eroding until a new equilibrium level is established--in the extreme case the beach can virtually disappear; if the supply is somehow enhanced, the beach will widen (i.e., "accrete") until equilibrium is established once again.

2. The shoreline area in which the sand travels is altered. If the shoreline is interrupted by a structure or altered by excavation or dredging, it must be expected that the flow of sand will be interrupted. The consequence is usually an accumulation of sand on the updrift side of the structure or within the excavation and at least temporary starvation of the beach on the downdrift side due to elimination of the sand supply to it.

3. The source of energy for the system is altered. There are several ways in which this disruption can occur. Sometimes only subtle changes in offshore bathymetry can produce marked variations in the energy of the waves that impinge along a shoreline [60]. Such changes can occur naturally or can be the result of excavation or deposition of dredge spoil.

All too often protective structures fail to accomplish their intended purpose, or they necessitate corrective action elsewhere on the coastline, because of their disruption of the beach equilibrium. The construction disturbances may also cause long-term adverse effects such as elimination of beach area and maintenance dredging of harbor inlets. To prevent such troubles it is necessary that a thorough study and comprehensive protection plan be developed before structures are authorized. Detrimental structures already in place should be scheduled for removal or replacement at the earliest opportunity.

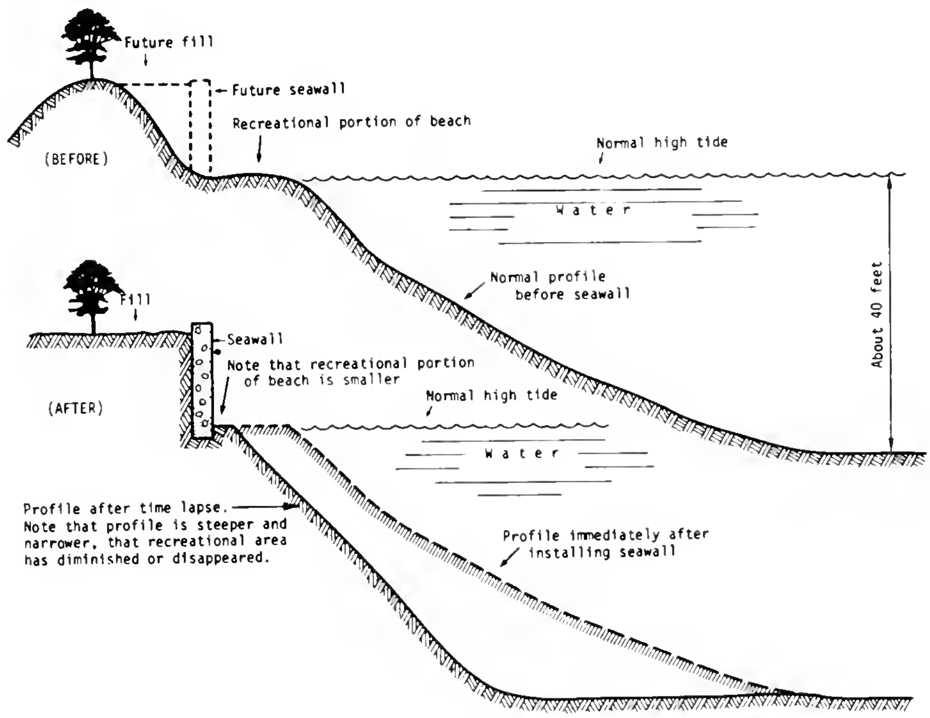
The solution to beachfront management is not to go exclusively with either structural or nonstructural techniques but to achieve a balanced plan emphasizing the nonstructural. Although it might be simplest to let nature take its course, extensive areas of the coast are already occupied and must somehow be maintained safely until setbacks and other protective land-use plans can be implemented. Yet even these systems should be allowed to remain as close to their natural dynamic states as possible. Some structural interference may be necessary, however, to stabilize inlets for navigation purposes.

The principal shore protection structures include seawalls, revetments, groins, jetties and breakwaters. Each serves a special purpose, and each affects beaches in a specific manner. They may have complex secondary effects. There are numerous example of structures causing, or contributing, to destabilization of beaches.

4.4.2 Seawalls

A seawall is a solid barricade built to protect the ocean shore and to prevent inland flooding. In principle, the seawall is designed to absorb and reflect wave energy, as well as to hold beach sand or fill in place and to raise the problem area above flooding elevations. Unfortunately, seawalls are expensive and commonly accelerate the loss of sand as the wall deflects the wave forces downward into the beach deposit (Figure 18) [61]. If the deflected wave forces erode away sand at the footing of the structure, the beach will disappear and the seawall can become undermined and collapse.

Figure 18. Erosion of beach area caused by wave energy deflected in front of a seawall (Source: Reference 55).

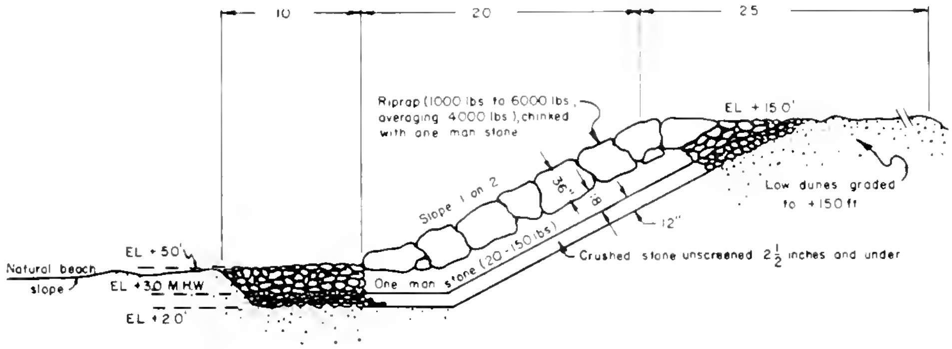


4.4.3 Revetments

Revetments are built to absorb and reflect wave energy at the beach front and are constructed from one or more layers of rock (riprap) or concrete placed on the slope face of a dune or bluff (Figure 19).

Revetments constructed of crushed stone and large riprap are generally more desirable environmentally than solid-faced seawalls. If properly designed and constructed, they will permit the natural flow of groundwater and runoff to pass through the structure. Other ecological advantages of revetments include a design that can easily be built to conform to the natural configuration of the shoreline, and a submerged area of the structure that permits the attachment of aquatic organisms.

Figure 19. Stone revetment at Cape Henry, Virginia (Source: Reference 51).



4.4.4 Groins

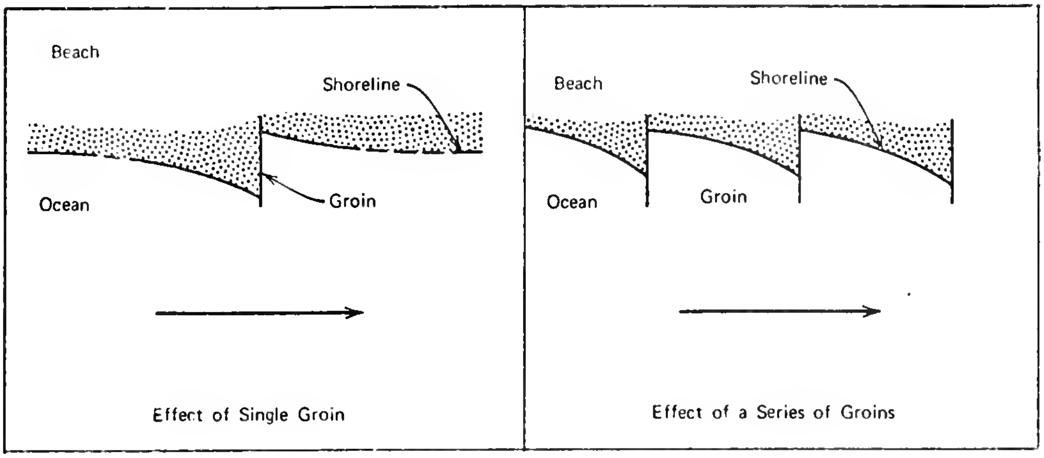
Groins are structures built at right angles to the beach to interrupt and trap longshore sand movement (littoral drift) in order to stabilize or widen a beach. Groins are constructed of timber, steel, concrete, or rock [62]. The trapping of sand by a groin is done at the expense of the adjacent downdrift shoreline.

Groins are effective (1) when there is a significant volume of littoral drift, (2) when the drift carries coarse materials (greater than 0.2 mm), and (3) when the beach downstream from the groin can be sacrificed (the sand gained at one place is denied to another) [63]. A row of parallel groins tends to force the littoral drift of sand offshore because much of the sand moves from tip to tip of the groin instead of moving along close to the beach, thereby causing sand starvation of the whole length of the beach (Figure 20) [62]. When a jetty system is constructed in a coastal area, fill between the structures should be required to assure natural beach equilibrium.

4.4.5 Jetties

Jetties are structures developed to modify or control sand movement at inlets. They are constructed of steel, concrete, or rock, depending on foundation conditions, wave climate, and cost. Although jetties are longer and larger and are generally found at inlets or major physiographical breaks in the shoreline.

Figure 20. The effects of groins on littoral drift (Source: Reference 64).

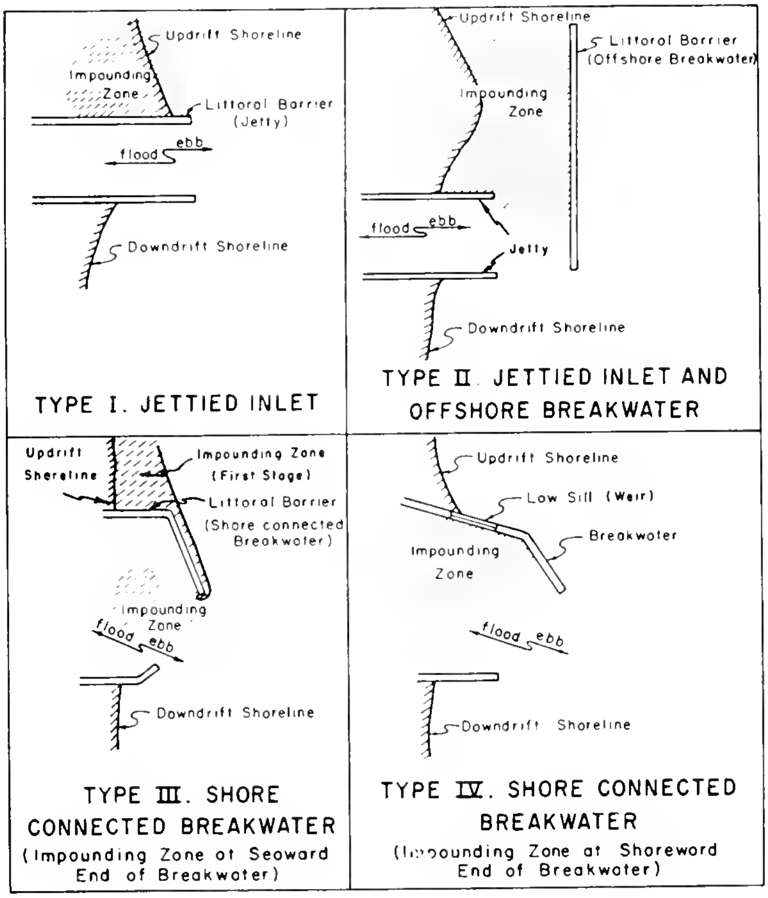


Jetties generally stabilize the location of the inlet channel and protect vessels from the direct force of waves. Sand is impounded at the updrift jetty and much is lost into deep water at the seaward end as the littoral drift process attempts to maintain sand movement. The supply of sand to the shore downdrift from the inlet jetty complex is thus reduced, causing erosion of that shore [64]. To eliminate undesirable erosion on the downdrift side of the jetty, some inlets are provided with a bypass system for dredging the impounded sand. These bypass systems are designed to ensure a flow of sand to nourish the downdrift beach and prevent shoaling of the entrance channel (Figure 21). This may also be accomplished in conjunction with an offshore breakwater.

4.4.6 Breakwaters

Breakwaters are constructed to break incoming waves and to provide safer passage for vessels through inlets as well as prevent sand blockage of them. When placed on the updrift side of a navigation opening, a breakwater may impound sand, preventing it from entering the navigation channel. They also afford shelter for a dredge to routinely pump sand across the navigation opening back into the stream of sand moving along the shore [51]. However, in the absence of wave action to move the sand stream, deposited material builds seaward toward the breakwater. The buildup actually serves as a barrier to littoral sand drift, depriving the downdrift beaches of sand [66].

Figure 21. Types of breakwaters and littoral barriers where sand transfer systems have been employed (Source: Reference 65).

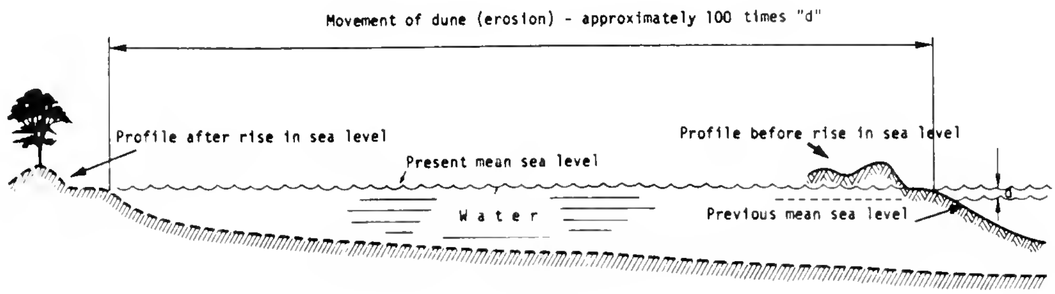


4.4.7 Nonstructural Approach

The nonstructural beachfront management program has as a goal the preservation of the natural beach profile. It has two essential elements which should be considered together. First, permanent upland development should be placed well inland of the active part of the shore, including receding shores that would be expected to become active in the future. Second, policies should be adopted both to prevent the removal of sand from any storage area and to prevent blocking the free transport of sand from any one storage area back into the active part of the system.

A setback line should be established to prevent the placement of structures too close to the active beachfront. The line should be far enough landward to allow predictable recession of the beach in a reasonable period of time, usually as long as the "useful length of life" of the structure. Because of current general rising sea level, setback lines may require frequent review as increased sea height forces the beach inland and the shore profile adjusts to equilibrium (Figure 22).

Figure 22. Recession of beachfront in response to a relative rise in sea level over a shore slope of one percent (Source: Reference 55).



Artificial beach nourishment is a desirable method of beach protection in many situations and is nearly always preferable to structural methods. If the beach reduction is due to natural causes, any effort to maintain the beach is probably futile. If it is due to man-made disruption of the equilibrium, man must become involved in the system to the extent that he has disrupted it. He must provide sand and often the energy to keep it moving [56]. However, nourishment projects should not become substitutes for balanced long-term beachfront management.

With the recent knowledge of the ecological values of estuarine ecosystems (and of the fact that estuarine sands are often too fine to withstand ocean currents) estuarine and bay sources are usually not considered available for beach nourishment.

Also removal of sand is known to threaten the beach profile because of reduction of storage, whether taken from dunes, the beach itself, or from the longshore bar or nearshore submerged bottoms. Shore erosion problems would not necessarily be solved by bringing sand from some other part of the same beach system.

The two major sources of beach nourishment are the open ocean and inlets or other areas of accretion where the supply is constantly repleneished by natural forces, particularly when navigation dredging is continuously required.

The feasibility of exploitation of offshore deposits has been established by the Corps of Engineers, but the technology appears to need improvement [56]. However, the sand reserve beyond a depth of 30 to 50 feet is generally independent of the sand reserves of the beach area, and therefore its removal should not upset the beach profile [60].

4.5 SITE PREPARATION - SUBPROJECT 5

Site preparation includes clearing, grubbing, rough grading, and other preliminary (or temporary) activities involved in the initial preparation of the site for development. Important considerations are the preservation of buffer areas and vital habitats, slopes (insofar as drainage is concerned), runoff and erosion control provisions, and surface water system protection. Properly controlled, site preparation activities can have minimal impacts on fish and wildlife resources except for the lands which are directly occupied by the development.

4.5.1 Summary

Site preparation activities will vary greatly according to local circumstances. However, specific constraints are needed in regard to project location, design and construction activity throughout the coastal region. The development and implementation of strict performance standards is required early in the site preparation phase to minimize potential operational and long-term problems.

Site preparation activities are numerous and each phase may produce a different type of environmental effect. The main activities are summarized as follows: (1) pre-site preparation activities, such as survey borings and facility layout design; (2) access road construction; (3) establishment of construction camps, and materials and heavy equipment storage areas; (4) land clearing, including tree and brush cutting, stump removal and rock removal; and (5) earth moving operations, such as rough leveling and grading. This discussion is mainly concerned with site clearing and grading activities. (Access roads are discussed in Subproject 8.)

Modification of the land area has a high potential for adverse effects on estuarine systems by altering runoff patterns and thereby reducing the capability of the land to store rainwater, to regularize its release from the watershed, and to cleanse it enroute to coastal waters. It is particularly important that barren soils be rapidly stabilized. Grades should be designed to direct water flows along natural drainage courses and through natural terrain where the existing vegetation can cleanse runoff waters. Watercourses and wetlands (marshes, swamps, bogs, creeks) should be exempt from alteration.

4.5.2 Location and Design

Before construction, the site should have already been properly selected to help avoid the vital ecological areas, flood-prone areas, aquifer recharge areas, and similarly sensitive sites, which if modified, could adversely affect coastal ecosystems. This assumes that local soil and groundwater conditions and other limitations have been considered.

Drainage: Assuming that the trees and other plant materials removed during site preparation are properly disposed of and surface watercourses avoided, the major problems of the clearing process itself are the loss of wildlife habitat associated with vegetative cover. Vital breeding, resting, and feeding areas should be identified, spared and surrounded with a suitable natural buffer area. The habitats of endangered species should, of course, be identified, preserved intact and buffered.

Scheduling of site preparation activities, especially clearing and grading, should avoid sensitive intervals of the seasonal fish and wildlife cycles, such as mating, rearing, spawning or migration. Also further benefits can be afforded by fencing off or posting "off limits" on the preserved habitat areas of the site.

Artificial land drainage requires careful control to ensure coastal ecosystem protection.

The following estuarine disturbances could be caused by runoff that is short-circuited by artificial drainage [67].

1. Abrupt changes in salinity.
2. Increases in turbidity.
3. Increases in nutrients (nitrogen).
4. Increases in biochemical oxygen demand (BOD).
5. Increases in coliform and other bacterial counts.
6. Decreases in dissolved oxygen.

Because of these potential adverse ecological consequences, projects that require the drainage of areas with high water tables for development should generally be avoided and more appropriate alternatives should be explored.

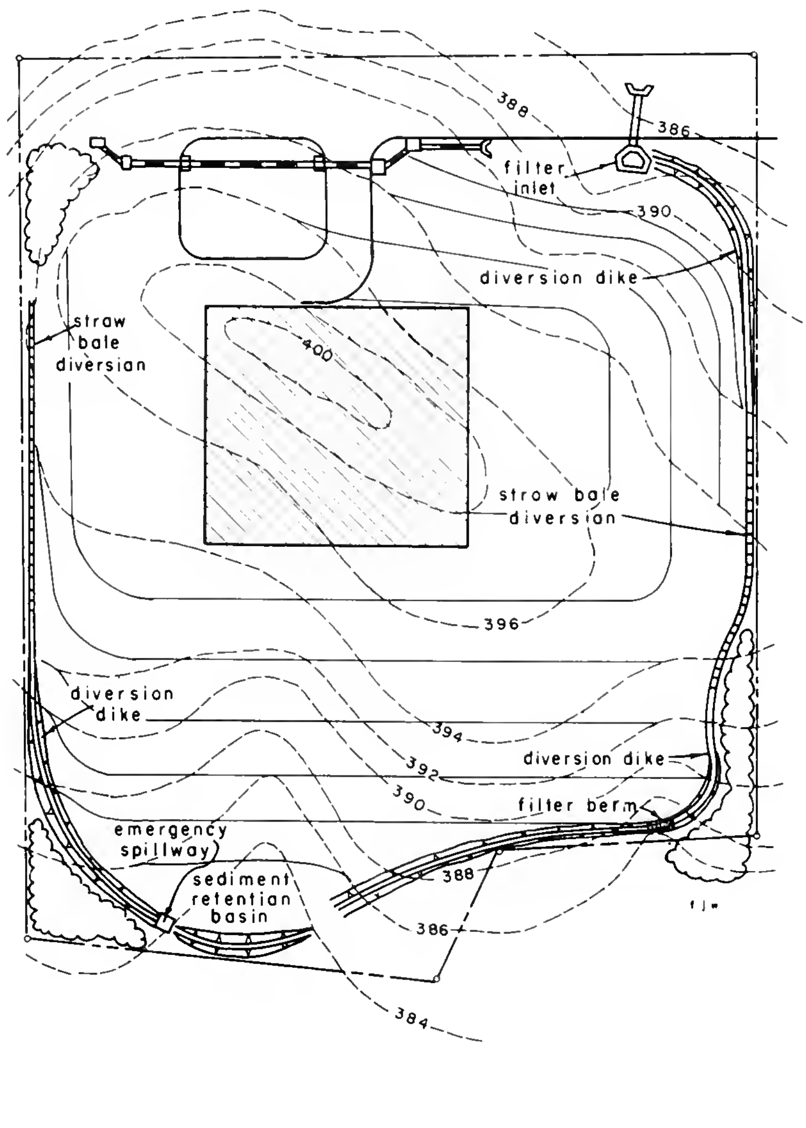
Wetlands: Site preparation activities must be controlled so that wetlands and other vital areas will not be altered in ways that will degrade their natural functions. In general, development activities in wetlands should be avoided that would obliterate the vegetation, disrupt the natural water flow, destroy the soil layers, or cause the drainage, pollution or drying out of wetlands.

There should generally be no filling of wetlands. The soil cover disrupts their function as completely as would excavation of them.

4.5.3 Runoff and Erosion Control

Stormwater runoff from construction sites often carries sediments, toxic materials, nutrients, bacteria, and other undesirable matter in quantities sufficient to pollute coastal waters. This flow should be managed with appropriate erosion controls and land drainage techniques to protect coastal ecosystems. These techniques can be divided into three

Figure 23. A sample sediment and erosion control plan (Source: Reference 68).

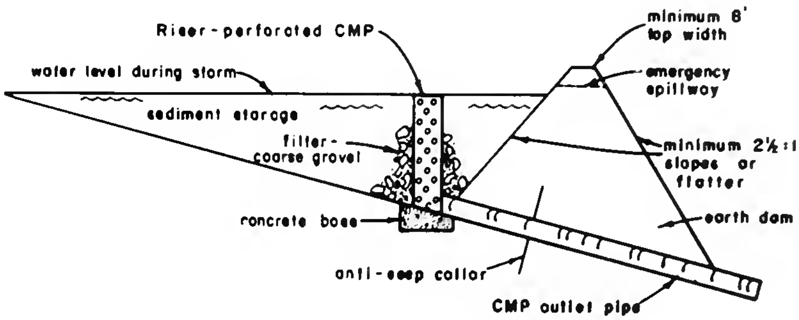


functional types: (1) trapping of sediments with vegetated buffer strips and detention ponds; (2) diversion of runoff away from likely erosion areas through grading, diversion cuts, and lined channels; and (3) prevention of soil movement and erosion, by reseeding, mulching, and the placement of netting over exposed soils (Figure 23).

Vegetated buffer strips and artificial control systems such as sediment basins can provide sound erosion control for on-going construction operations. Buffer strips should be planned for all watercourses and shorelines in order to trap sediment and other pollutants. Their width should be determined according to the slope of the land, the severity of erosion, and the existing vegetation types.

Sediment basins (Figure 24) detain runoff and trap sediment, thus preventing increased turbidities in adjacent water bodies [69][70]. Such devices are required practice in many states and coastal communities.

Figure 24. A temporary retention basin that prevents serious water pollution from eroded soil (Source: Reference 68).

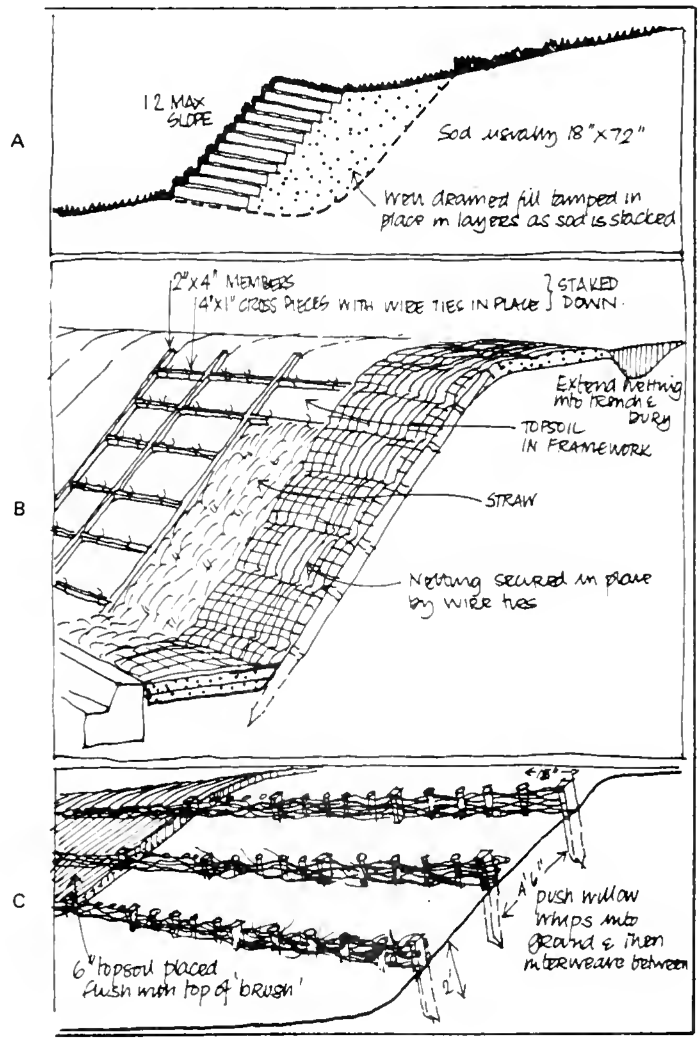


Diversion is also an effective method of erosion control. Runoff can be channeled away from exposed soils with small parallel diversions or troughs cut to intercept the surface water flow. Bench terraces can be constructed across a slope to direct water either into sediment basins or vegetated buffer strips where accumulated sediments can be removed.

Grassed waterways (swales) can be used effectively in many situations but are most effective in removing moderate amounts of sediment. The grass protects the channel against erosion by reducing the velocity of the water at the soil surface. The most suitable grasses to use are those that produce a dense uniform cover near the soil surface, are long lived, provide protection during all seasons of the year, and are able to withstand the impact of sediments.

Soil stabilization can prevent soil movement and erosion. Once site alteration has commenced, immediate steps should be taken to stabilize barren soils. Many state and local development regulations require immediate restabilization of cleared areas. Three common methods used are revegetation, mulching, and sodding (Figure 25).

Figure 25. Sod (A), straw mulch (B), and willow whips (C), three methods for protecting a steep slope from soil erosion (Source: Reference 71).



Plant cover is easy to establish and maintain in locations that have fertile soils and moderate slopes. If construction is delayed on a site that has been cleared and graded, temporary cover crops can be used to protect the site against erosion. Rapidly growing plants such as small grains and grasses are best [70].

Immediate mulching and reseeding of bare earth can eliminate significant soil loss. Generally, mulch is applied at rates of 1 to 2 tons per acre [69]. Jute netting can be applied to soils to protect newly seeded areas until vegetation becomes established. Although cotton or paper netting can be used [70], jute netting is particularly well suited because it can withstand the higher flow velocities associated with ditches, steep slopes, and similar areas where the establishment of vegetation is difficult [69].

4.6 SITE DEVELOPMENT - SUBPROJECT 6

The activities included in site development are those that immediately follow the grading and other initial preparation of the site surface. They include a range of activity from finish grading to the erection of structures. Provision must be made early in site development planning for many environmental protection features, such as detention basins, stormwater treatment facilities and sewage lines. Site development activities which incorporate adequate design features can be conducted with minimal impacts on fish and wildlife and their habitats beyond those from the site clearing itself.

4.6.1 Summary

Since there is a large diversity in OCS-related onshore facility components and requirements, and a variety of engineering approaches to a given type of project, site development plans may vary greatly according to specific local conditions and project needs. General performance standards and environmental safeguards can be used to guide development on a wide variety of sites for OCS onshore and induced community facilities.

Major activities of site development include filling and finish grading, paving, permanent transmission line construction activities, open excavations and permanent drainage facilities, erection of structures and special projects as required, such as bulkheads, bridges, dikes and levees, and sewage systems (as discussed in their respective Subprojects).

Major changes in the natural pattern of land drainage usually causes adverse effects on water quality. Such changes include filling or devegetation of drainage-ways, alteration of land grades, channelization of watercourses and paving. Therefore, site development should always consider the principle of retaining the system of land drainage in as nearly the natural pattern as possible. Construction in wetlands is therefore virtually precluded.

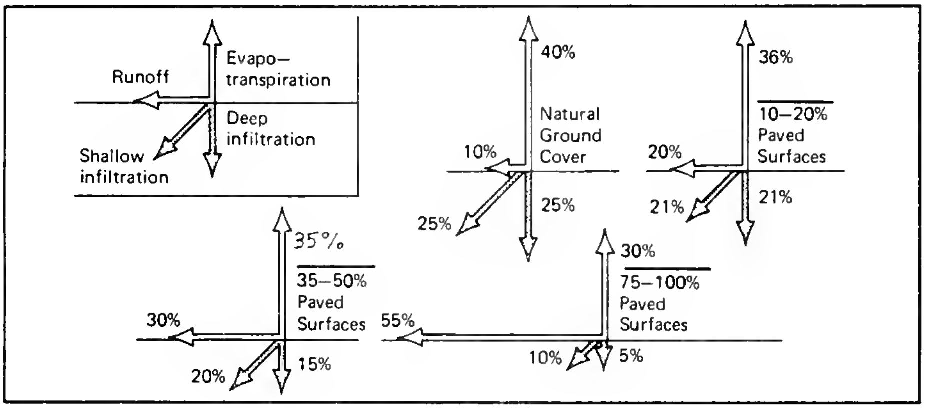
4.6.2 Finish Grading

Since land surface alterations may increase the volume and rate of runoff, finished grades should be designed to direct water through natural terrain and drainage courses, where the vegetation and soils can cleanse the runoff waters and reduce erosion. Barren soils should be stabilized by replanting vegetative cover as quickly as possible after grading.

4.6.3 Paving

Paved surfaces bypass the natural purification system of soil and vegetation (Figure 26). Seepage into subsurface aquifers is blocked, and

Figure 26. Typical hydrographic changes due to increasing the area of impermeable paved surfaces in a developing area (Source: Reference 71).



rainfall moves directly into surface waters. Among the continuing effects of paved surfaces are (1) sedimentation, resulting from the erosion of soil by runoff from impermeable surfaces, (2) reduction in groundwater recharge due to increased impermeable surface area and accelerated runoff, and (3) addition of pollutants such as lead, zinc, and oil to coastal waters. In a developed, or developing, area the amount of runoff increases proportionately with the extent of impervious surfaces and rooftops.

Alternatives to paving include gravel, crushed rock, or crushed shell. Gravel can be used for some parking lots and secondary roads. Crushed stone, because its shape and larger size limits compaction, may be suitable in soft muddy areas or on sites prone to erosion.

There are other suitable paving materials made of concrete, brick, and metal. Examples range from lattice concrete blocks to standard paving bricks with corner lags to control spacing to perforated bricks [71]. Porosity varies with the subsoil and the amount and type of subsurface gravel.

4.6.4 Line Construction

On-site line construction activities, including pole and power lines, underground communication lines, and small pipelines, will normally disturb only a small amount of land and, if expeditiously restored, may have minimal effects on fish and wildlife resources. Excess spoil generated from these construction corridors may cause a spoil placement problem.

4.6.5 Erection of Structures

The activities of construction should have minimal environmental effects providing no adverse effects are caused by foundation excavation. However, the operation of trucks, heavy equipment, and other supporting activities could have a variety of adverse effects. Heavy metal contaminants may be released from metal fabrication, paints, and other building materials and supplies used during construction.

4.6.6 Open Excavations

Canals built to drain lowlands or to facilitate navigation can affect the ecosystem. For example, waterway excavation can (1) pollute coastal waters, (2) preempt vital habitat areas, and (3) alter natural water flow patterns. (For details see Artificial Waterways, Section 4.7.)

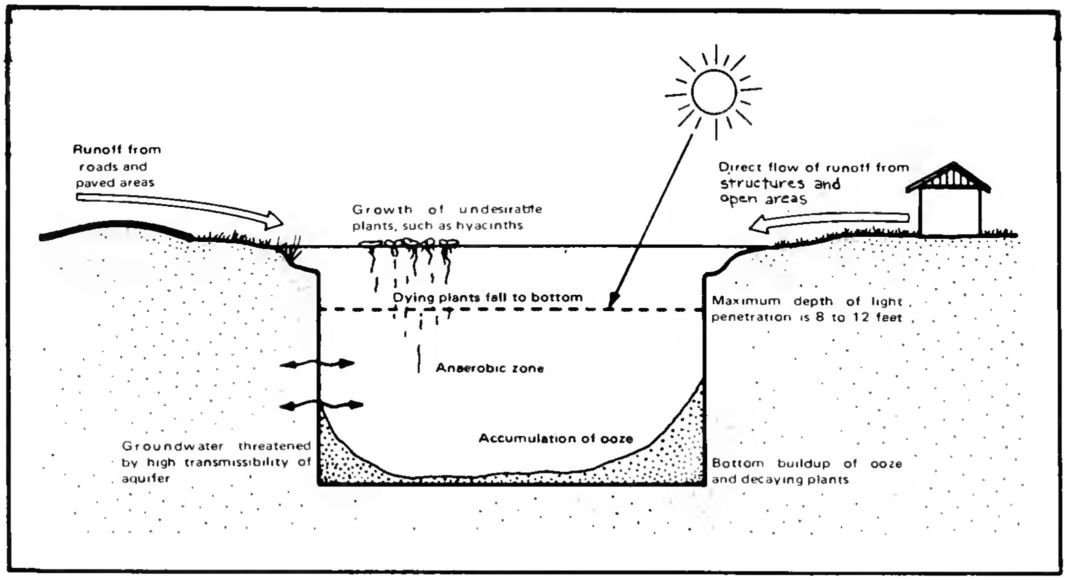
In areas with high water tables, excavation should be confined to works that are specifically designed to preserve the natural water system. Artificial basins should be shallow and have gently sloping vegetated earthen sides (Figure 27). Artificial basins should be surrounded by a buffer strip of vegetation for bank protection and filtration of runoff. Dead-end canals serve as traps for silt and organic ooze, accumulating deep beds of anaerobic materials which cause persistent lowering of oxygen to unacceptable levels. During storms such sediments partially flush out into estuarine waters, causing stress through the reduction of dissolved oxygen levels.

Land drainage has a particularly high potential for adverse effects on fish and wildlife resources. When water tables are lowered with drainage canals, the natural flow pattern is disrupted, the water-cleansing function of the vegetation is eliminated, and runoff occurs in surges.

4.6.7 Wetlands Safeguards

The natural characteristics of wetlands are so valuable that perservation of their functional integrity should be miantained and, if possible, integrated with man-made alterations. Any use

Figure 27. An improperly designed artificial lake or borrow pit (Source: Adapted from Reference 72).



of these wetlands should accordingly be oriented toward light-duty, non-altering uses. If properly controlled, relatively small alterations should not have detrimental effects on water systems and estuarine resources. Nevertheless, any structure should be designed and built to reduce the harmful effects of shading, water flow interruption, and site disruption.

Solid-fill roads or other structures in wetlands obstruct water flow. Roadways built through wetlands or over wetland swales should be elevated on pilings rather than placed on fills.

As a rule, discharge or release of pollutants into the wetlands should be prevented. There may, however, be some capacity for the wetlands to absorb certain storm runoff pollutants and thereby to function as a "land treatment" system. Any such pollutants should not exceed the calculated receiving capacity of the system and should not degrade surface water or groundwater below allowable standards.

4.6.8 Filling

Landfill is a problem mostly where wetlands or watercourses are involved. Wetlands should not be bulkheaded and filled (see Section 4.3). Natural watercourses should not be blocked by solid fill; appropriate size culverts or bridges should be used (see Section 4.8). General fill should be stabilized as rapidly as possible with vegetation or artificial means (see Section 4.5).

4.7 ARTIFICIAL WATERWAYS AND WATER BODIES - SUBPROJECT 7

Canals and ditches of many kinds are cut for various access, drainage, fill and conveyance purposes. They are dug to drain shorelands for agriculture, and for home building and mosquito control. Canals, ponds and lakes sometimes result from dredging to provide fill for housing, dikes and roadbeds. Other purposes of canals include access for barges and inland navigation, placement of transmission lines, and conveyance of stormwater, power plant cooling water and (to a limited extent) irrigation. Such waterways characteristically disrupt water flow patterns, degrade water quality, and infringe on vital habitats.

As used here, artificial waterways are those that are cut through the intertidal zone (including wetlands) or the shorelands (channels dredged in Section 4.1). Artificial watercourses are built in conjunction with many of the subprojects examined in this section.

4.7.1 Summary

The construction activities discussed here relate mainly to drainage of land, excavation for fill, and dredging for navigation.

OCS facilities may require artificial waterways, water bodies, or canals for laying overland transmission lines, for navigation, for building dikes around storage tank areas, for miscellaneous site drainage purposes, and perhaps, for graving docks in platform fabrication yards. Also road and rail links to service bases and repair yards may involve construction of canal just for equipment access. These activities may cause significant adverse effects such as vital habitat alteration, disruption of water flow, water quality degradation, and saltwater intrusion.

Secondary development induced by OCS activities such as recreation or housing often involves canals, ditches, or artificial lakes.

4.7.2 Navigation Canals

There are thousands of miles of navigation canals in the United States that extend inland from the coast. These range in size from large commercial waterways, like the Houston Ship Canal, to homeowner projects aimed at bringing the family boat closer to the backyard.

While navigation canals have a high potential for adverse ecological effects, they preempt wetlands, increase saltwater intrusion, unbalance salinity regimes in coastal waters, upset nutrient cycles, and compartmentalize ecosystems. For coastal canals, the net effect of alteration is usually, but not always, adverse to fish and wildlife resources. The particular circumstances of each canal vary so widely that they may generate different sets of effects on fish and wildlife resources.

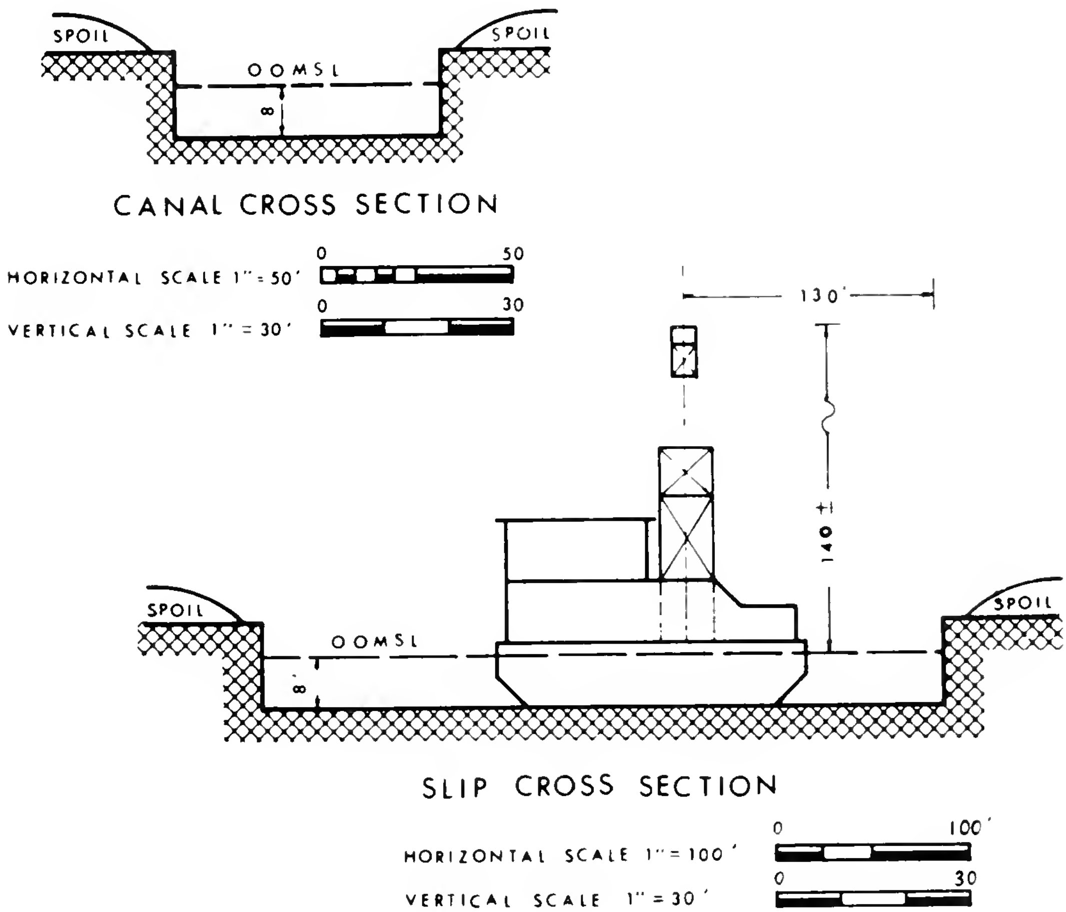
Perhaps the most dramatic alterations caused by canal building have been experienced in the oil and gas recovery operations of the Louisiana lowlands and wetlands. In a 5,258 square mile area, bounded by the Mississippi River and the east levees of the Atchafalaya Floodway and extending to the Gulf, 106 square miles of canals (2 percent of the total area) were built. Oil and gas industries are responsible for nearly 65 percent of the total, drainage canals account for almost 21 percent, and navigation canals for over 10 percent [42] (Figure 28). Most of the canal dredging involves access to drilling locations or laying of pipelines. Secondary canals for crude-oil transport barges and production workboats are also common.

In the Louisiana coastal zone, suction-dredged spoil is typically deposited in small hillocks or mounds in the vicinity of the tail pipe where the slurry is discharged. Sometimes in large jobs it is impounded by dikes. This is done where it is desirable to build an embankment or elevated area for construction, or when the material is to be used as future borrow material [42]. Bucket dredges, which are the Louisiana workhorses, usually leave a continuous embankment of spoil along one or both sides of the canal. Spoil bank dimensions depend on the size of the excavation, the length of the boom, and the stability of the canal and spoil banks [42].

In some cases, a dragline is mounted on a marsh buggy (a motorized, tracked vehicle with flotation pontoons) to lay pipelines through the marsh areas by cutting a ditch for floating in the pipe, thus avoiding the need for a full-size canal for a pipeline-laying barge. This type of operation produces smaller canals and far less spoil, but the marsh buggy tracks may have pronounced adverse effects on the marsh surface [42].

Through these various canal building activities, the integrity of the natural environment is altered. Land has been lost directly through canal dredging, and natural drainage and tidal circulation have been altered. Erosion rates are increased because of increased length of land-water edge and the increase in the volume of water exchange. Bank erosion caused by wakes of boats is a particular problem. However, the spoil banks become habitat types in themselves. Raised several feet above the surrounding water, they develop high-ground vegetation types. Some that have been in existence for over 20 years have viable stands of oak and other large trees. Their potential use by wildlife and as a recreation base may be high [42],

Figure 28. A typical configuration of a canal and oil drilling barge slip in Louisiana (Source: Reference 42).



The following guidelines prepared by the Louisiana State Planning Office are among those recommended for canal dredging in the Louisiana marshlands [73].

1. Where possible, existing channels should be used.

2. Dredging operations should be carried out as quickly as possible in order to limit siltation of oyster beds and other marine areas and minimize extended light reduction.

3. Spoil banks should not exceed plus one-half foot MSL in elevation and should be lower where possible.

4. Openings in spoil banks should be maintained at predetermined intervals in order to allow free passage of water, nutrients, and aquatic life between the marshland and the channels.

5. The construction of impoundments should be limited. Impoundments decrease flooding and increase evaporation and temperatures, resulting in an adverse change in environment for various biota.

6. In some situations in order to retard erosion of spoil banks and subsequent filling of channels, stabilization by riprap or vegetation may be considered.

7. Care should be taken to avoid dredging during wildlife migrations, spawning, and nesting times.

8. The seaward ends of canals should be plugged until excavation is complete. Where canals cross a bayou, the ends emptying into the bayou should be plugged.

9. Spoil from dredging should be disposed of in some predetermined manner based upon the environmental situation under consideration. Options range from local to (if feasible) deep and open-water disposal.

10. Spoil can be used in certain activities to advantage. For instance, dredged material may be used to nourish beaches or to control the erosion of river banks. Under some circumstances it can be used to stabilize estuarine lake and bay shores.

11. Upon abandonment of an area, the levees should be removed in order to try to restore the area to its former condition.

4.7.3 Excavation for Fill

Many artificial waterways are created primarily to obtain fill to raise the land surface of low-lying coastal areas. When this type of site development occurs, the borrow areas may be fashioned into lakes or boat canals to provide extra benefits. Such projects may have serious ecological effects.

Waterfront housing developed by dredging coastal systems and using the dredged material to fill and elevate the land may be very damaging to natural resources, particularly when the dredge spoil is piled on adjacent wetlands or low lands to gain elevation and to create lots for canal side homes. Such projects affect the ecosystem adversely in three major areas: (1) water quality, (2) habitat, and (3) ecosystem productivity.

The canals often collect pollutants and become foul particularly from septic tank effluents.

Artificial lakes often act as accumulation basins for septic wastes and organic material, causing depressed oxygen conditions to prevail [74]. Water quality degradation in these man-made lakes typically increases over time, often accelerating as adjacent lots are occupied. The lakes gradually accumulate pollutants and sediments and can become grossly polluted if not properly designed and maintained.

All artificial basins should be surrounded by a buffer strip of vegetation to maintain runoff water quality. Furthermore, the edge configuration of lakes should provide for acceptable wildlife habitat with growth of cattails [74].

4.7.4 Drainage of Land

Canals and ditches are often excavated to facilitate drainage of low-lying coastal lands for a variety of development purposes. Such projects vary greatly in form, dimensions of the cut, disposal of excavated materials (spoils), and ecological effects. Onshore development of OCS facilities may require drainage of sites in some situations as may secondary development of surrounding communities and support facilities. Drainage projects may dramatically upset the natural shorelands water system with serious adverse effects on terrestrial ecology, as well as the estuaries that benefit from the natural flow of land runoff.

Canals that convey fresh water to coastal areas also function in the reverse, that is, to convey salt water inland. The intrusion of salt water upstream in artificial canals often has serious adverse effects on inland systems, rendering the water unsuitable for freshwater fish and wildlife. Seawater encroachment can contaminate human and agricultural water supplies, necessitating costly treatment for relocation of intake points. Increased salinity also results in increased corrosion and shorter life expectancy for engineered structures [61].

As a general rule, excavation of canals and ditches in wetlands should be avoided because the wetland function is seriously disrupted, vegetation is lost, water flow is disrupted, soil layers are destroyed, pollutable catchments are formed, and the drainage and drying out of wetlands is facilitated.

4.8 ROADWAYS AND BRIDGES - SUBPROJECT 8

This subproject addresses roadways and bridges built in the coastal shorelands, along the edges of water basins, or across the basins. In the absence of environmental safeguards, coastal roadways and bridges have a potential for disturbance, including alteration of fish and wildlife habitat, disruption of water flows and a reduction in the general quality of terrestrial and aquatic ecosystems. Indirectly, coastal roadway systems may induce new forms of land use along the road corridor which would also preempt natural habitat areas and waterways. Adequate consideration of natural systems and the proper alignment and design of roadways and bridges can substantially reduce major adverse effects to fish and wildlife and their habitats.

Neglect of important biological relationships in estuarine crossings has had proven adverse consequences to fish and wildlife resources. For example, in 1960 the FWS reasoned that construction of a combined causeway/bridge from the mainland to Sanibel Island could eliminate the scallop population of Pine Island Sound, among other adverse effects. Nevertheless, the bridge was completed (in 1963), and, unfortunately, the scallop population was exterminated. The apparent cause was an unfavorable rise in salinity in the breeding areas northwest of the causeway [75].

4.8.1 Summary

OCS-related industrial development in coastal regions may create a demand for new and improved roadways and bridges. They are built to facilitate an increase in commuter, raw materials, supplies, and equipment traffic. In relation to secondary development induced by OCS activities, new road systems may be required to service expanding commercial, industrial and residential areas. While railroad construction might occasionally be required, the subject is not considered separately here because potential disturbances are analogous to those from highways.

Major disturbances to fish and wildlife resources may occur when roadways and bridges transect vital areas, or impinge upon floodplain areas. The nearer the roadway is to water, the greater is its potential for pollution and habitat alteration. In the past, the solid-fill approach to building road systems in wetlands was prevalent; however, the environmental and cost benefits of elevated roadways have begun to make them widely recognized as an appropriate alternative.

The construction of coastal road systems may also have long-term adverse impacts, such as alteration of subsurface drainage patterns from excavation, water circulation blockage from continuous lateral spoil banks, and pollution from roadway runoff.

4.8.2 Highway Systems

In locating a roadway, bridge, or causway, it is necessary to consider the land and its resources as a total natural system. Highway system planning then aims at identifying and setting priorities for various uses and amenities and concurrently assessing environmental and cultural effects. All roadways in coastal areas should be located to conform with existing topography and require a minimum of alteration of soils and vegetation. Other factors demanding consideration include community, institutional, and residential values, the value of land for recreation, surface-water and groundwater values, as well as fish and wildlife resource values. With these values considered, roadway location can then be best determined to simultaneously serve the purposes of preservation of natural systems and need for urban expansion [76].

4.8.3 Roadways

Location and Design: A major adverse environmental effect of highway location in water areas of the coastal zone has been the replacement of extensive marsh and mangrove wetland areas with the roadbed or with dredge spoil mucked out for the roadbed. A second major effect is the disruption of normal circulation patterns, both tidal and land drainage. A third major impact is the creation of mud waves undulating out from and parallel to the highway fill. These waves of mud are created by the pressure of the roadbed on organic soils. Marshes over 100 yards away from roads have been buckled and disrupted by mud waves. These actions have had pronounced negative environmental effects on the carrying capacity of affected estuaries.

Because of the potential for the preemption and disturbance of wetlands by roadways, it has become U.S. Department of Transportation policy to avoid wherever feasible the drainage, filling, or interference with wetlands or the water sources supplying them [77]. Bridges and pile-supported causeways can be incorporated into the design plan to reduce interference with wetlands and watercourses.

Roadways along the shoreline should be located sufficiently landward of the existing beach and dune line to permit natural beach recession and beachfront sand movement for the expected life of the roadway.

Construction: The disturbances from highway construction in wetlands, intertidal marshes, and other ecologically vital areas hold a great potential for environmental disruption even if roadways are properly designed.

In shorelands, roadway construction, operation, and maintenance activities should be controlled to prevent erosion and sedimentation, obstruction of groundwater recharge, alteration of stream flow, and increased pollution and eutrophication of coastal waters.

Construction activities that need control are excavation of borrow material, cuts and fills, land clearing, grading and recontouring, and stream channelization or realignment. Excess fill or spoil may be deposited on marsh areas to dispose of such materials or to create a storage area for heavy equipment and supplies [76][78]. Construction supply storage areas should be placed above the annual flood mark, and equipment access roads should be placed only in the actual roadway corridor. After construction activity is completed, the area should be restored to its original state by removal of spoil banks and other construction debris that will adversely affect environmental quality.

Even with the best safeguards, temporary adverse effects can result from construction activities. Therefore, it will often be necessary to avoid work during particularly critical periods of migration, breeding, feeding, and other functions of aquatic life.

Operations: Effects related to the day-to-day use and maintenance of roadways are usually of lesser impact but can be significant in certain situations. Continuing disturbances occur because of altered runoff from road surfaces, soil erosion, and the introduction of salts, herbicides, and street surface contaminants into nearby watercourses.

4.8.4 Causeways

Solid-fill causeways have the potential for a number of adverse environmental effects including degraded marshes and choked-off bays and tidal tributaries. Any type of solid-fill causeway can disrupt the natural tidal flow in an estuary sufficiently to upset the delicate salinity balance essential for the survival of many estuarine organisms. Besides obstructing tidal flushing, causeways also act as water barriers during severe storms and hurricanes. For example, a water pileup behind the causeway in the late 1960's killed all of the ground-nesting birds in the Pelican Island National Wildlife Refuge [79].

Location and Design: The construction of a number of highways through marsh areas has effectively separated the upper reach of a tributary system of a wetland from the lower reach, completely altering the circulation patterns of the entire marsh system. The blockage has prevented the normal circulation of waters and exchange of nutrients and organisms and lowered the productivity of the coastal system [80]. The effects of such "dams" could be minimized if pilings and piers had been used for construction instead of solid-fill causeways. The basic circulation pattern of the tributary wetlands or streams may be preserved by appropriate use of culverts under filled causeways.

Solid-fill construction usually requires extensive dredging for fill and the excavation of construction canals, which result in additional loss of wetlands and tidelands, soil discharge into the estuary, disruption of water flows, and mud waves.

The extensive use of construction channels for barge access to construction sites has changed water flow patterns, even when the completed highway is elevated on pilings. Such channels are usually perpendicular to water flow and become repositories for silts, sediments, and organic pollutants. The resultant conditions produce many of the adverse effects of stagnant holes and dead-end canals.

When building an elevated roadway over wetlands, construction should take place from the roadway structure and away from adjacent wetlands to the maximum extent possible. Heavy equipment needed to place the roadway pilings (cranes, dredges) should be operated from the roadway. This topside construction is recommended to avoid the need for barge construction canals.

The choice of an elevated structure instead of a filled causeway has important economic implications. The greater costs of a structure are justified when the cost of "mucking out" and replacing the soft sediments with firm fill is greater than the cost of constructing an elevated structure. The costs of elevated structures, which minimize the use of fill, have been comparable with those of solid-fill causeways when there is about 10 to 12 feet of "muck" and usually have been lower when deeper trenches are required [81]. According to a recent Louisiana study, elevated structures may become a cost-effective alternative to solid-fill causeways in only 3 feet of muck [82]. Also, the time period to reach the 95 percent compaction point, required before road pavement can be laid, increases exponentially with any depth increase past 10 feet [81].

The cost efficiency of causeways appears to be declining because of the increased value of wetlands and increased costs of fill.

Spoil Disposal: Solid-fill causeway construction and barge canal excavation often create a spoil disposal problem. Vital habitat areas are not suitable disposal sites, and acceptable sites that are easily accessible are becoming scarce. The remaining alternatives are to transport spoil either well inland or to the ocean. To minimize disposal problems, roadway designers should anticipate and eliminate whenever possible any requirement for dredging.

4.8.5 Bridges

Structures over the water should be designed to maintain the natural water flow and circulation regime [83]. Bridges should be designed so as not to impair tidal flow in respect to volume, velocity, or direction. Abutments should be built back from the water edge, and clear spans used rather than piers. Most simply, the cross-sectional area of a watercourse should not be reduced by abutments, support piers, pilings, and so forth.

Poorly designed and constructed bridges act as partial barriers to natural water flow. In many urbanized bays, impairment of water circulation by bridges results in a buildup of pollutants to adverse levels, as well as shoaling problems. For example, the piers supporting the Great South Bay Bridge on Long Island, New York, have been shown to slow water flow. A Federal study concluded that restricted circulation west of the Bay Bridge was a contributing factor to the degradation of water quality in the area [84].

When bridge abutments or fill areas must impinge on water areas, it is necessary to reduce the encroachment to meet flood protection requirements. The cross-sectional area of a waterway should in no case be reduced to less than that which can adequately pass the 100-year maximum flood waters.

4.9 GROUNDWATER SUPPLY - SUBPROJECT 9

Many onshore OCS facilities are big users of fresh water, often pumped from groundwater aquifers in the coastal area. Such facilities as refineries, petrochemical complexes, and platform fabrication yards may withdraw particularly large amounts of groundwater. If withdrawal exceeds safe limits, aquifers may become contaminated with salt or the land surface may sink or both.

Principal causes of saltwater intrusion into coastal aquifers include (1) rapidly developing coastal areas where demands for fresh water overdraw the aquifer, (2) canal or navigation construction that may dig into ground levels providing direct access between surface saltwater and freshwater aquifer soils, and (3) land-use changes which increase acreages of impervious area and disrupt the natural recharge of aquifers.

4.9.1 Summary

Water supply systems for OCS-related demands are primarily concerned with groundwater extraction. Groundwater resources are under growing pressure in coastal communities and are increasingly pumped for industrial and domestic water use. In California, Florida, Louisiana and New York, groundwater aquifers have already been overpumped and have become contaminated by saltwater intrusion. Other coastal areas are rapidly approaching this situation. With as little as two percent contamination by salt water, a drinking water supply cannot meet federal potable water standards.

While land subsidence is not a common problem, the adverse effects of the instances of its occurrences are so severe as to make it a problem of general concern. The solution to protecting groundwater and land resources from saltwater intrusion and land subsidence is sound and comprehensive water management. A total management program provides for groundwater, surface water, and reused water supplies to be inventoried and utilized in a coordinated plan of "conjunctive" management. Where extensive withdrawal may cause saltwater intrusion in the freshwater supply, a water control program is implemented to reduce the harmful amounts withdrawn and allocate the water resources according to historical uses [85].

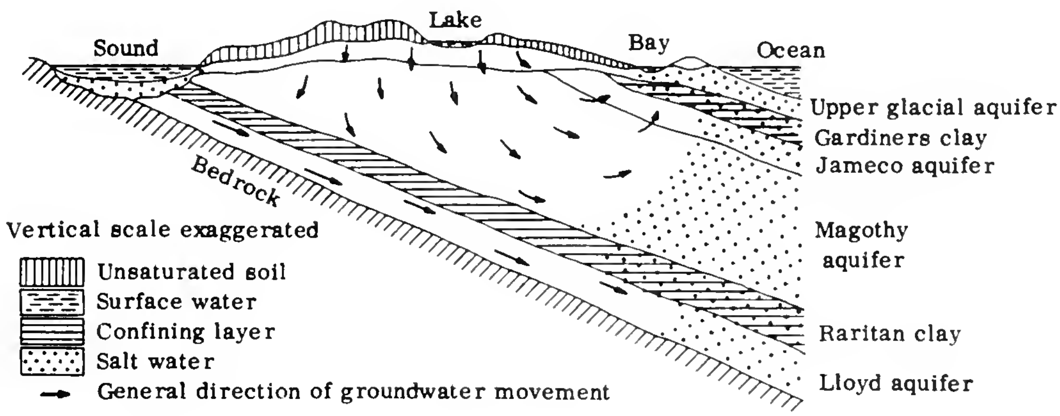
A comprehensive water management plan requires information on the supply of groundwater, the source of replenishment of aquifers (recharge areas), the potential for contamination and depletion, and the possibilities for reclaiming wastewater and minimizing unnecessary water consumption.

4.9.2 Saltwater Intrusion

Saltwater intrusion, as used here, is the advance of salt water into groundwater aquifers (in another context it refers to displacement of fresh water or less saline water by more saline water).

Surface aquifers vary in level with seasonal changes in rainfall, sometimes rising above the land surface and flooding it, but usually remaining below at a depth of several inches to many feet. There may also be a number of deeper, geologically confined aquifers, which are separated from each other and the surface aquifer by more or less horizontal layers of impermeable rock or clay (Figure 29). Typically, the confined aquifers

Figure 29. A typical profile of aquifers of Long Island, New York (Source: Reference 86).

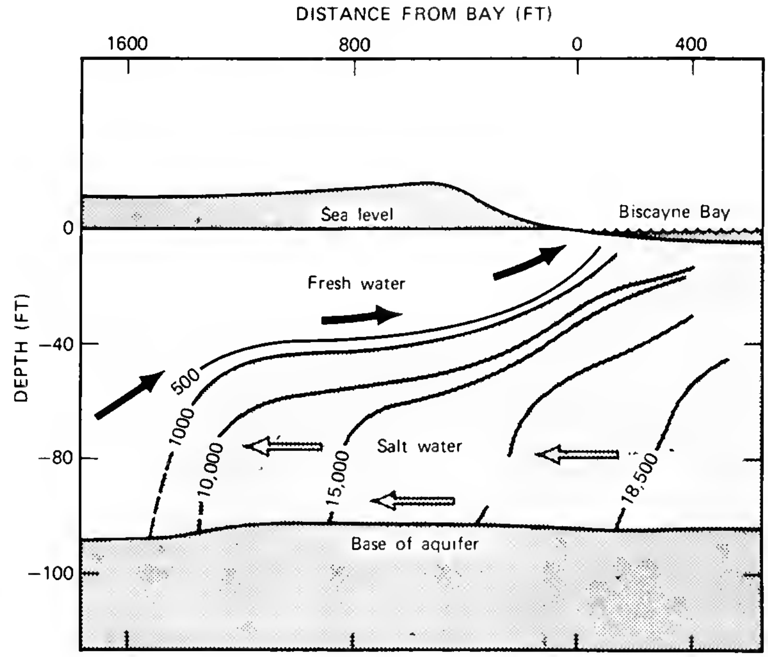


are sloped seaward with fresh water flowing out of them where they intercept the seafloor. The interface between salt water and fresh water under natural conditions is a zone of transition (Figure 30). The head pressures on the aquifer normally prevent salt water from intruding far into the fresh water, but overpumping may reduce this pressure and allow intrusion from the saltwater layer. Along California's populated coast there has been seawater intrusion in aquifers in at least 12 localities, 7 others are known to be threatened, and 15 others are regarded as potential intrusion sites [85]. Most other coastal states have actual or potential intrusion problems along their seacoasts.

4.9.3 Subsidence

Subsidence of the land surface from over withdrawal results because the land loses the subsurface support provided by groundwater (Figure 31).

Figure 30. The pattern of saltwater intrusion (salinities in parts per million) of the Biscayne aquifer in the vicinity of Miami, Florida (Source) Reference 87).

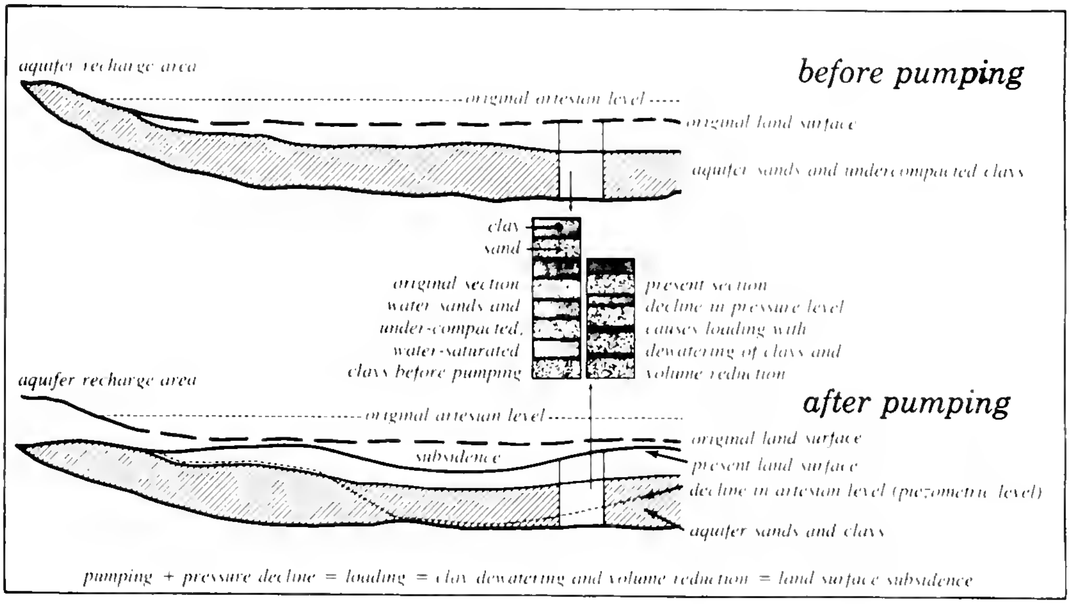


In the heavily industrialized areas around Galveston Bay, Texas, particularly at the southern end of the Houston ship channel, extensive land subsidence caused by excessive industrial groundwater withdrawal has occurred. The subsidence rate has been increasing since the 1940's and is predicted to continue. The bay area land has sunk as much as 8 feet below sea level [89][90] (Figure 32).

Subsidence increases the danger of flooding. Dikes have been built and pumps installed to help ward off flooding problems from subsidence. Unfortunately, such structural and technical protection measures treat only the "symptom" of unmanaged groundwater pumping, i.e., the increase in relative sea level and flooding [89].

The solution is a groundwater management plan. Management would include the entire equifer system since water withdrawal in one area ultimately may affect the entire aquifer. The patterns and schedules of recharge and extractions of water would be regulated. The management program would specify the number and location of wells, their pumping rates and annual limitations on total extractions.

Figure 31. The effects of withdrawal of water from an aquifer (Source: Reference 88).



4.10 SEWAGE SYSTEMS - SUBPROJECT 10

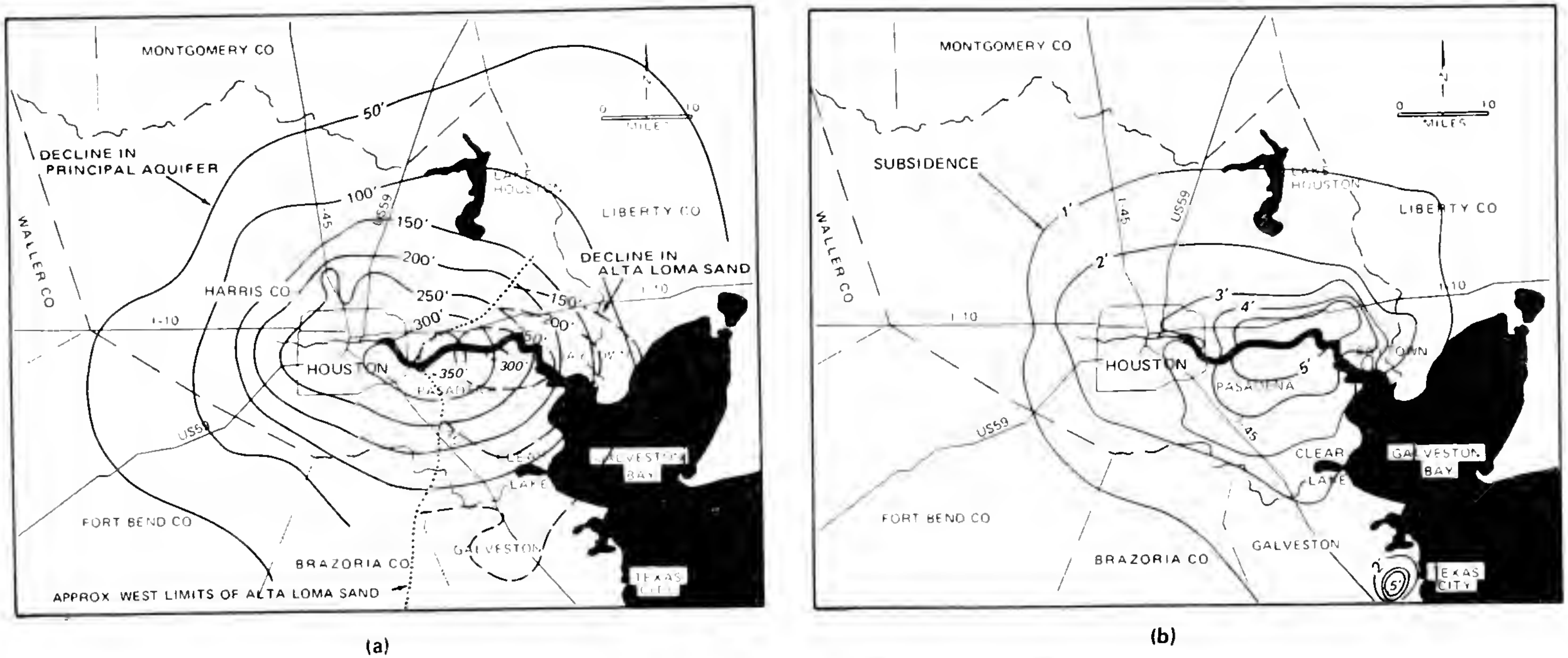
While the amount of sewage generated by an OCS facility in a densely populated area would be an insignificant addition to the total, a large labor-intensive facility in a rural coastal community could have a significant impact if it does not construct a sewage plant. The increased population from induced employment and the families of workers, as well as the OCS facility, may place demands on local sewage systems.

4.10.1 Summary

Sewage is any waste material carried by sewers and may contain, in addition to household domestic wastes, wastes from industries, institutions, and commercial establishments and runoff from streets and highways. The accumulation of these wastes presents a real threat to the coastal ecosystem if they are not properly collected, treated, and disposed of.

Five major pollution problems caused by inadequately treated human and industrial wastes in the effluents from coastal sewage plants are (1) hazard to shellfish and human health, (2) aesthetic offenses, (3) oxygen reduction of coastal waters from biological oxygen

Figure 32. The effects of overpumping the groundwater on groundwater level decline (a) and subsidence (b) in the Houston-Galveston Bay area, Texas, in the period from 1906 to 1964 (Source: Reference 89).



demand (BOD) loading, (4) eutrophication, and (5) release of pesticides, heavy metals, and other toxins. Of these impacts the most insidious is eutrophication.

Central sewage treatment facilities have the potential for protection of coastal waters if properly designed and operated. If not, they may only accomplish a transfer of major pollution from dispersed sources to a concentrated point source in coastal waters. Most existing sewage systems are in the process of being upgraded to meet the minimum requirements for the protection of coastal ecosystems.

A proper septic tank system releases effluent into the drainfield with no harmful effects and with all the benefits of simplicity and economy. In low-lying areas with naturally high water tables, however, liquid waste from septic systems may saturate the soil, rise to flow over the surface of the ground and into the coastal waters. This pollution potential is exacerbated in floodprone areas, where high tides and storms periodically supersaturate the soil. These conditions weigh heavily against the use of septic tanks in lowlands and in favor of central sewage systems.

4.10.2 Siting Considerations

In coastal regions, wetlands often have been the most easily available area for the location of treatment facilities and the least expensive, even when the problems and costs of filling and general site preparation are considered. In addition, the collection mains (trunk mains) have often been routed through wetlands, where inexpensive land is available and wastewater can flow easily by gravity to the treatment plant.

The use of wetlands as sites for sewage plants is now generally considered environmentally unacceptable. This may also apply to sewage pipelines.

Shallow estuaries tend to have poor flushing characteristics so the longer that discharged sewage effluent remains concentrated in a water body, the more pronounced will be its effects. Therefore, it is often infeasible to discharge sewage effluent into a local estuarine water body even after treatment. The requirement to discharge in other than an estuarine water body may have important consequences on selecting a sewage plant site.

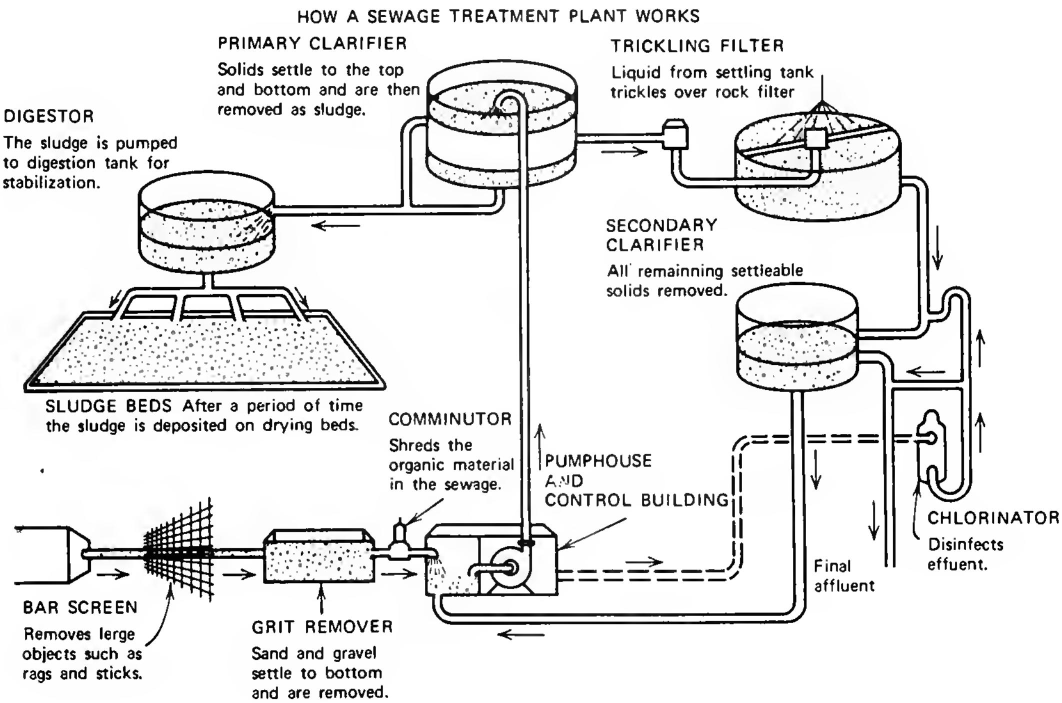
An issue open to resolution is whether certain deep bays and sounds should be classified as "oceans" and thus be acceptable receiving waters for secondary effluent. Since secondary treatment does not remove all bacteria and is of very uncertain value in terms of virus removal, outfalls in bays and sounds could endanger fish and wildlife resources and habitats. The decision will depend wholly on local conditions affecting dispersal, dilution, and assimilation of pollutants [91]. Disposal in bays should occur only if land application, open ocean disposal, and tertiary treatment cannot be proved applicable.

4.10.3 Conventional Treatment Systems

Primary and secondary levels of waste treatment are in common use. In primary treatment,solids are usually screened or allowed to settle and are removed from the water.

In secondary treatment,wastes are further purified through the use of biological processes (Figure 33).

Figure 33. Components and processes of a secondary sewage treatment plant (Source: Reference 92).



Unfortunately, secondary-treatment plants remove up to 90 percent of the organic matter but less than half of the nitrate and phosphate nutrients in sewage (Table 23). The effluent is discharged with nitrate values as high as 15 to 50 ppm, which may be 1000 times greater than the natural levels of healthy coastal waters [94]. Discharge of effluent with such a high concentration of nitrate causes overfertilization of confined and poorly flushed estuarine waters [95][96]. Resulting algae growth can cause high turbidities, reduced dissolved oxygen, and the accumulation of

Table 23. Average Efficiency of Primary and Secondary Sewage Treatment Plants (Source: Reference 93)

Chemistry	Removal efficiency of treatment: Primary %	Removal efficiency of treatment: Primary Plus Secondary %
Biochemical oxygen demand	35	90
Chemical oxygen demand	30	80
Refractory organics	20	60
Suspended Solids	60	90
Total nitrogen	20	50
Total phosphorus	10	30
Dissolved minerals	–	5

dead organic matter on estuarine bottoms. In serious cases, the nutrients remaining after conventional secondary treatment may have to be removed by an additional process before discharge of the effluent to typical estuarine waters.

Ocean dispersal of treated sewage may be feasible if properly designed and controlled, and provided that high concentrations of toxic substances are absent. The pripcipal advantage of the ocean as a disposal site is a reduction of costs compared to the advanced treatment required for disposal in estuarine waters (Table 24) [98]. The ocean rapidly disperses and dilutes the effluent because of its volume and mixing capabilities, thus reducing the potential for ecological damage. The location and physical configuration of ocean effluent outfalls should be determined by depth, distance from shore, circulation and mixing features of the particular ocean location, and factors influencing interactions of wastes with the environment [99]. But it must be clearly understood that high concentrations of sewage released at a single point anywhere in the ocean may overwhelm its assimilative capacity and cause extensive local damage, particularly to bottom life.

Table 24. Length of Ocean Outfall for Secondary-Treatment Effluent That Can Be Constructed at Cost of Conversion to Advanced Wastewater Treatment (Source: Adapted from Reference 97)

Flow (Million gallons/day)	Increase in Annual Cost to Convert from Secondary to Advanced Treatment (Dollars)	Annual Cost Per Mile of Sewage Outfall[a] (Dollars/mile)	Cost-Effective Outfall Length[b] (Mile)
1	178,500	30,800	5.8
10	712,000	131,000	5.4
100	4,560,000	256,000	17.8

[a]For secondary treatment effluent.

[b]Cost equal to cost of advanced treatment for same volume of wastewater flow.

4.10.4 Improved Treatment Systems

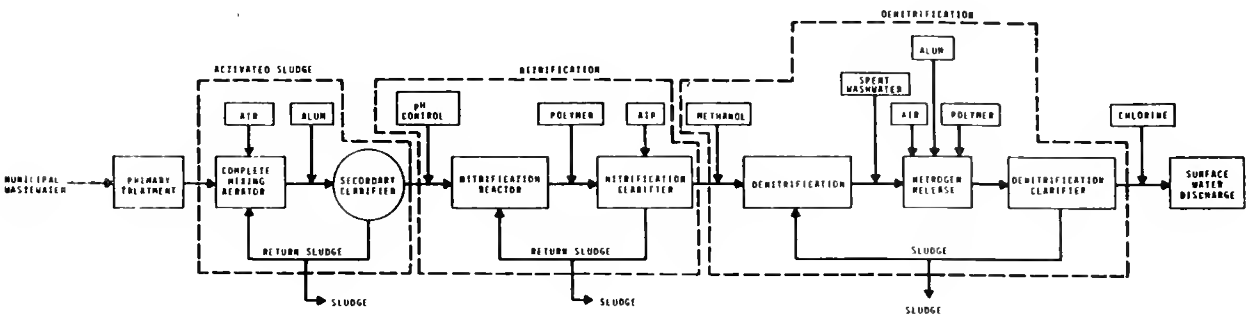
Extended treatment may be required for sewage disposed in estuaries in the future because the assimilative capacities of estuaries are so low that they would be overwhelmed by discharge from secondary treatment plants.

Advanced, or tertiary treatment requires moving beyond the simple mechanical and biological methods employed in primary and secondary treatment to incorporate more advanced techniques, such as coagulation-sedimentation, adsorption, electrodialysis chemical oxidation, nitrification-dentrification or a combination of these [100] (Figure 34).

An effective alternative to dumping sewage effluent into coastal water bodies is land application of wastewater. The feasibility of this approach is demonstrated by the more than 500 municipalities in the United States that use some form of land application for disposal or treatment of wastes [102].

In the land application system, wastewater is applied by spray irrigation or overland flow to a land surface, where it is cleared by biological, chemical, and mechanical processes and/or filters through the soil as it travels over a vegetated surface. Finally, it either filters into the groundwater or is collected for discharge to a water body, depending on the system used. In an optimum treatment system with

Figure 34. Advanced wastewater treatment showing the biological-chemical method employed to activate sludge treatment with alum addition and nitrification-dentrification (Source: Reference 101).



appropriate slopes (3 to 6 percent) and vegetation (e.g., canary grass), 130 acres (53 hectares) may handle the municipal wastes of 10,000 people people [97]. Package plants, designed to treat the wastes of small 50- to 150-unit developments, may be particularly amenable to this type of soil and vegetative restoration.

4.10.5 Combined Systems

Normally it is not practicable to combine stormwater with the sanitary sewage system because plants are likely to be overwhelmed during heavy storms with the result that volumes of untreated sewage overflow to coastal waters. The additional plant capacity required to effectively handle the large amounts of water received during peak storms is enormous and entails great capital expense.

Some pollutants in raw industrial wastewater that are discharged into municipal collection lines may pass through municipal treatment facilities unchecked. In some cases, industrial sewage so discharged contains sufficient biocidal substances to reduce the efficiency of municipal facilities to purify domestic sewage.

To avoid any complications that might arise from trying to treat both types of sewage with a combined facility, which could require costly modifications of locally operated sewage treatment plants, dual systems should be designed so that each type can be treated separately from the other.

Safeguards should be instituted to ensure that raw or improperly treated industrial wastes are not accidentally discharged into municipal lines.

4.10.6 Septic Tanks

If the necessary water and soil requirements can be met in the coastal zone, and if septic systems are properly maintained and operated within their physical capacities, they should be adequate for their purposes and central sewage systems will not be needed.

There are three major ecological issues relating to septic tanks in coastal areas: (1) wastes leached into coastal waters when septic tanks are located too close to the shore; (2) tidally induced high water tables that provide direct and rapid flushing of drain fields into coastal waters; and (3) inadequate drain field components or soil absorption characteristics that cause tanks to overflow, particularly during rainstorms, and pollute coastal waters. The solution to these problems lies in proper location of septic tanks in relation to water.

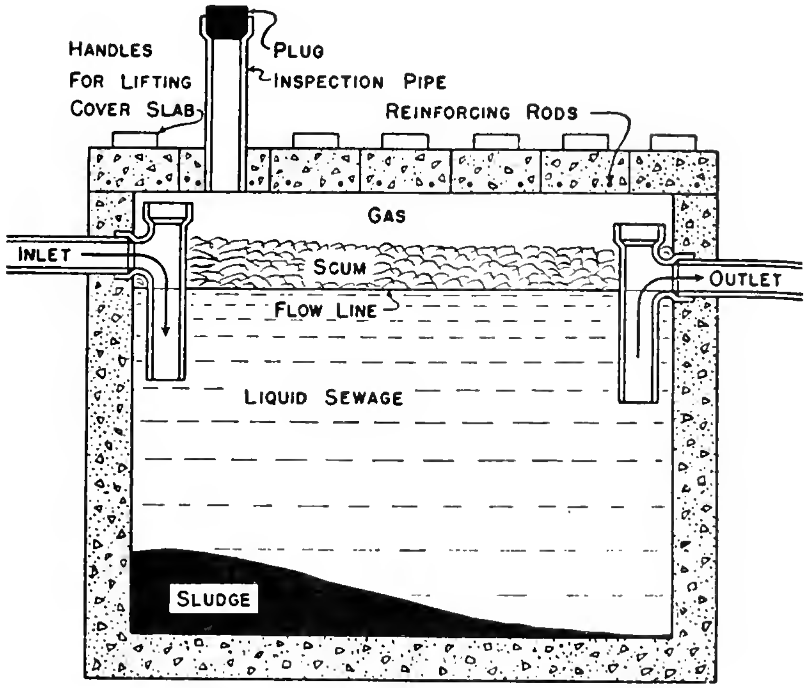
Health officials aggressively promote central sewage systems as the inevitable and proper alternative to septic tanks. From an ecological viewpoint, however, septic tanks may be quite acceptable if properly built and operated. However, poorly designed septic tank systems leach chemical contaminants to groundwater and thence to surface waters.

A septic system is a microcosm of a land sewage treatment system. Wastewater from one or several homes flows into a concrete septic tank, where the solids settle to the bottom to be decomposed by bacteria into organic matter (Figure 35). Nutrients are released during this partial solids digestion and flow into drainage areas through subsurface tiles to percolate through ground for removal. The nutrients are often taken up locally by trees and shrubs, or are adsorbed to soil particle surfaces. The drainage field functions to provide final purification within the soil. If the distance between the septic system and surface waters is insufficient, the liquid waste leaching through the soil is inadequately treated. Consequently, it reaches the water basin in contaminated condition, injecting a variety of substances, the most troublesome of which are nutrients, particularly nitrogen compounds. Periodically the resulting sludge in the bottom of the tank must be removed and disposed of.

How well a septic tank sewage disposal system works depends largely on such factors as soil permeability, groundwater level, stratigraphy, the distribution of soil types, and slope [103]. Because shoreline soils typically have poor percolation and drainage characteristics and shallow water tables, often less than 5 feet [104], soils in shoreline areas typically impose severe septic tank limitations.

Nitrate is particularly troublesome, as it is extremely soluble and mobile in groundwater. There is no national standard for the amount of nitrate (or phosphate) allowed in coastal waters. But one may presume a concentration higher than 0.2-0.5 ppm to be potentially adverse. The storage and biological recycling of nitrate is a complex matter and the selection of a fixed numerical value is elusive.

Figure 35. Typical septic tank detail (Source: Reference 92).



Scientific studies have shown that the nitrate form of nitrogen is commonly found in high concentrations (up to 40 ppm) at distances of 100 feet from septic systems. Other studies have shown unacceptable amounts of nitrate at 150 feet [105][106]. Consequently, a setback distance at least 150 feet inland of the annual flood line is required to minimize nitrate pollution. After extensive review, L. B. Leopold concluded that "for soil cleansing to be effective, contaminated water must move through unsaturated soil at least 100 feet" and that "...it might be advisable to have no source of pollution such as a seepage field closer than 300 feet to a channel or watercourse" [107]. Local regulations have typically required the absorption fields of septic tanks to be set back a minimum of 50 feet from the edge of the water--stream, lake, open ditch, or other water body into which unfiltered effluent could escape.

Even with an appropriate setback there may be problems with refusal of saturated or impermeable soils to accept septic tank effluent. A major consideration of efficiency is the rate at which effluent moves into and through the soil. The amount and type of gravel, sand, silt, and clay influence this rate, and movement is faster through sandy and gravely soils than through clayey ones. Soil permeability for septic tanks should be moderate to rapid, allowing a percolation rate of at least 1 inch per hour [103].

Normally, septic systems should be avoided where there is a high water table (typically, if closer to the surface than about 10 feet). If the groundwater beneath the septic tank absorption field rises to the level of the discharge pipes, the saturated soils cannot absorb the effluent. The groundwater may become grossly polluted. In the worst situations the unpurified effluent may even rise to the surface, where it will drain directly into an adjacent water body.

Properly spaced septic tanks on slopes of less than 15 percent usually do not create serious problems if soil properties are adequate for sewage absorption; however, on steeper slopes, controlling the downhill flow of the effluent may be difficult. Steep slopes can allow improperly filtered effluent to reach and contaminate receiving waters [103].

Several other precautions may also be observed. Overflow pipes, which convey sewage directly to the water basin when the septic tank fills, should be prohibited. Seepage pits should be discouraged in favor of septic drainage fields. Finally, septic tanks and similar private sewage treatment facilities should be inspected on a regular basis by the local health department to ensure proper working order and adequate treatment.

4.11 OVERLAND TRANSMISSION SYSTEMS - SUBPROJECT 11

Overland transmission systems are a natural outgrowth of OCS-related community and industrial development. Transmission lines for oil, gas, electricity, water, sewage, and telephones and various booster or pumping stations are the primary system components. Proper location and construction of these components can reduce their impact upon both the narrow utility corridors they occupy and the entire inland ecosystem. This subproject covers only buried (or underground) transmission systems onshore.

4.11.1 Summary

Overland transmission systems serve as linkages between onshore facilities and community growth areas. Oil and gas-related facilities, such as oil refineries, petrochemical plants, gas processing plants and market terminals are linked to each other and to their source of oil or gas by pipelines. These originate at oil tank farms near marine terminals, LNG regasification plants, or landfalls of marine oil or gas pipelines. All of these facilities are also served by utility transmission lines for phones, electricity, water and sewage, and possibly natural gas. Additionally, induced growth in nearby communities creates a demand for these utility services and transmission lines.

The principal focus in this subproject is upon oil and gas pipelines which are a direct result of the siting of oil and gas transmission facilities and processing. The disturbances caused by other types of transmission lines are similar to those caused by oil and gas pipelines, but are often smaller in scale.

Construction activities may disrupt soil, vegetation, ecologically vital areas, and fish and wildlife habitats. The greatest ecological damage may occur from excavation.

The pipelaying method used for oil and gas lines depends upon the type of terrain to be crossed. If a pipeline crosses wetlands in which there is no firm ground to support equipment, a canal 40 to 50 feet wide may be needed. Lay barges are usually utilized in such areas. The dredged material will be placed alongside the canal and form a low, flat levee, punctuated periodically by openings to allow drainage. With required openings and bulkheading (plugging the ends), erosion, saltwater intrusion and disruption of drainage patterns are reduced. In firmer wetland areas, a smaller canal about 10 feet wide will be dredged and backfilled using equipment on working mats or pads. On firm land, the routine trench and backfill method is used, which is the same technique by which water and sewer lines, cables, and so forth are buried.

The severity of the impact depends greatly on the characteristics of the site. On flat upland sites the impact may be temporary, since severe erosion of disturbed soils should not occur and vegetation and habitat effects would be localized, providing that the site is restored to pre-construction conditions. However, where pipelines cross rivers and wetlands, the impact potential is much larger as disruption of soils could cause greater erosion and downstream sedimentation affecting both aquatic and terrestrial habitats. Long-term modifications in water quality, water table levels, and vegetation could result if water-holding properties of soil layers in wetlands were not restored to pre-construction conditions [7].

In developing overland transmission systems, then, provisions should be made for: (1) maintaining the natural shoreline; (2) minimizing dredging; (3) arranging proper disposal of spoil; (4) avoiding wetlands; (5) eliminating runoff erosion, (6) backfilling; (7) maintaining tidal exchange; (8) restoring vegetation; and (9) construction and maintenance of bulkheads or pilings at all crossing of natural tidal creeks and rivers throughout the project life.

4.11.2 Location

Location of transmission corridors is a key factor in reducing potential ecological disturbances. Corridors should be sited as much as possible on firm, dry ground. Wherever possible, pipeline routes should follow existing transportation and utility routes and corridors to protect previously undistrubed habitats from construction and development activities. Corridors should be planned to avoid vital areas such as fish spawning areas and wildlife breeding and nesting areas. Sensitive habitats such as dunes, wetlands and others should be avoided.

A rough estimate of the width of land disturbed by pipelines laid through wetlands or on land would be 50 to 60 feet. On dry land, a swatch of perhaps 50 feet would need to be maintained free of trees and large shrubs to permit maintenance vehicle access and surveillance for leakage [107].

4.11.3 Design

The design of transmission lines does not hold a high potential for reducing environmental disturbances. Nevertheless, a few design features are worthy of mention.

Transmission line corridors should be designed to accommodate an additional load to limit further construction in previously undisturbed areas and to avoid bisecting fish and wildlife habitats. Oil and gas pipelines should use the largest diameter pipe that is economically feasible to allow future oil and gas flows to be added without new construction.

Joints in sewer lines should be tight and should be monitored frequently. Couplings that will reduce groundwater infiltration and sewage escapement should be chosen.

In unpopulated areas, power and telephone lines should be left above ground to allow quick repairs and to avoid trenching. Pipelines and water and sewer lines should have periodic pressure monitoring stations to facilitate location and repair of troubles.

The pipeline should have leak or blowout preventives to shut off sections of the pipeline with pressure drops in the line. They should avoid seismic areas. When evaluating impact, it must be realized that cross country motor vehicles, bicycles, horseback riding, and other types of human disturbance may occur along corridors, particularly near urban areas.

4.11.4 Construction

There are four general methods used in laying onshore pipelines. The first of these is the dry land method. With this method a right-of-way is cleared of all vegetation, a ditch is dug, and the pipe is welded, lowered into the ditch and buried in place. Trenching involves from one to several pieces of heavy equipment, some of it very specialized. One type designed for the sole purpose of digging trenches consists of a large wheel with attached digging cups. As the wheel turns and removes the dirt, it is placed beside the trench in a continuous mound. Other trenching operations are also available. In most cases the trench is refilled with the soil that had been removed. When pipe has been placed in the hole, more soil may be available than needed and mounds which could alter local hydrology may remain. In organic soil the stockpiled soil may oxidize and there may be insufficient amounts of soil to refill the trench, and a depression may exist after pipeline placement which may divert natural water flow and provide a new route for salt water intrusion.

For landfalls where the pipeline from offshore intercepts the shoreline, a second method often used is the "pipe-pull" method. A trench traversing the beach and littoral zone is excavated (including any necessary blasting). After the trench is excavated, sections of pipe are assembled on the lay barge anchored offshore and pulled by winch and cable through the trench toward the shore.

The third method is the "push-ditch" or "shove" method often used in wetlands. A narrow, relatively shallow ditch is excavated from the bank by a dragline or clamshell digger. The ditch may be 4 to 6 feet deep and 8-10 feet wide. The pipe sections are joined together at the point of origin of the ditch, and the line is given temporary buoyancy by strapped floats and is pushed or shoved down the ditch. After being floated into place, the floats are cut loose and the line allowed to sink to the bottom of the ditch.

The fourth method of pipe laying utilizes a "floatation canal" to provide access for the pipe-laying equipment. Such a canal may be 40 to 50 feet wide and 6 to 8 feet deep, and may have an additional trench in the bottom to provide 10 to 12 feet clearance above the top of the pipeline. The pipeline is constructed on a series of lay barges and passed over the stern. This type of canal is excavated by a flotation dredge, which normally piles the spoils upon each side to form a low levee. Characteristically, this type of dredging is conducted where the marshes are soft and unstable.

In the past, levees beside the flotation canal were characteristically continuous with few or no breaks. More recently, after studies have shown the impacts caused, openings are required to be cut in levees in order to minimize disturbances to existing drainage and use patterns.

Of the four methods of laying pipe (dry land, pipe-pull, push-ditch and flotation), the push-ditch method results in the least amount of disturbance to the terrain and biota, which effect may be further minimized by backfilling and restoration. The push-ditch method causes a loss of approximately one acre per mile of pipeline construction (assuming a trench 8 feet wide) while the flotation method causes an estimated loss of 6 acres per mile of pipeline installed (assuming a trench 50 feet wide) [73].

Effects: Pipe burial operations have the potential for many ecological effects, including release of toxic matter from the sediments; increased turbidity and oxygen demand; and direct destruction of valuable habitat.

Environmental effects may be reduced by employing special construction and restoration techniques and by installing the most environmentally sensitive segments of the pipeline during periods of least vulnerability, avoiding spawning periods, rainy seasons, and spring blooms. The following construction techniques should be used:

1. Utilize the "double ditch" method in excavating trench spoil where the first six to twelve inches of soil with the vegetative root systems is stockpiled separately for replacement on the surface of the backfilled trench.

2. Backfill excavated trench materials from wetlands as soon as possible to minimize oxidation and releases of toxic chemicals into adjacent waterways or habitats.

3. Utilize clean, upland fill to supplement backfill material of trenches; fill to be at the same elevation as surrounding area to protect freshwater drainage patterns.

4. Do not deposit pipeline spoil materials in vital areas, such as wetlands, barrier beaches and estuaries. Provide frequent openings in trench spoil to prevent disruption to water circulation patterns of the area.

5. Utilize bulkheads (dams) in open trenches at each natural water crossing to maintain existing parameters of salinity, to retain salt/freshwater interfaces, to prevent saltwater intrusion and to restrict boat traffic which leads to erosion.

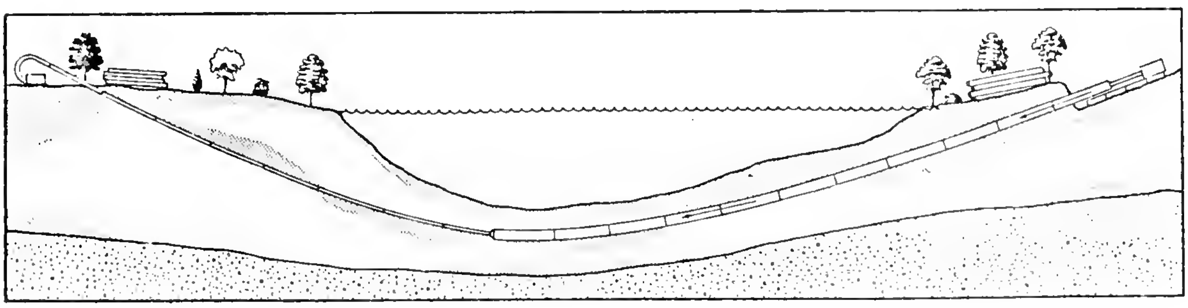
6. Confine heavy equipment operations to the area of construction and excavate only the area sufficient for pipeline operations. In coastal areas conduct construction activities from existing roads and causeways to avoid dredging canals for building purposes.

7. Utilize existing service roads and the pipeline corridors for access to protect previously undisturbed areas. If necessary, all roadways should be improved with strengthened shoulders and proper-sized culverts to insure unrestricted water exchanges.

In the course of laying a pipeline through marshland, open water may be traversed. The crossing of small water bodies or rivers has always presented environmental problems of excess siltation and sedimentation of the water body or downstream areas. Silts can be carried by currents and are usually most damaging to juvenile and sessile species. In addition the crossing area may be sufficiently disrupted that pre-construction conditions may not be obtained due to constant agitation and erosion from fast moving currents. Blasting or dredging may be required in these crossings.

An adaptation of oil well directional drilling techniques has been used to install pipes at river crossings, and while the techniques are more intricate than dredging a trench, the environmental effects are less. The method involves drilling the pipe in an underground arc from one side of the stream to the other (Figure 36).

Figure 36. Directional drilling technique for the installation of pipelines under rivers and streams (Source: Reference 108).



The advantages of boring a crossing section under a river or stream include the ability to work in any period during the year and completion of the project within minimal time, usually two to six weeks. Also, as the stream bed and its banks are undisturbed, costly bulkheading and other bank stabilization methods are eliminated. Weight coating the section of pipe is not necessary. The line is buried deep beneath the stream bed and as the earth above is undisturbed, there is no buoyancy problem. Additionally, there are no navigational hazards for large or small boats during or after construction.

4.12 STORMWATER SYSTEMS - SUBPROJECT 12

Site preparation and construction of OCS facilities, especially large ones in natural drainage areas, can drastically affect the extent, content and course of stormwater runoff.

Excessive alteration of the land surface in coastal area developments is the cause of considerable pollution and other disruption of coastal water ecosystems. Engineering and land use management actions can resolve many of these problems, particularly recent innovations in the structural and nonstructural handling of the stormwater runoff. This discussion addresses structural, or engineered, approaches. Nonstructural watershed management approaches are discussed elsewhere.

4.12.1 Summary

Changes in the natural pattern of land drainage are presumed to have adverse effects on water quality. Such changes include development in floodplains, filling or devegetation of drainage-ways, alteration of natural land grades, straightening or channlization of watercourses, land clearing, and land surfacing. Loosened soils may erode and be washed into water basins along with silt, heavy metals, fertilizers, pesticides and other deleterious matter. Extensive areas covered with a paved surface causes runoff of freshwater in surges which may affect salinity and currents as well as water quality. Development planning should respect the principle of retaining the system of land drainage in as nearly the natural pattern as possible. OCS-related developments should restore water cycles so that water leaves the altered area in virtually the same quantity and rate of flow as existed before the project.

In a developed area, the amount of stormwater runoff increases proportionately with the extent of impervious surfaces and rooftops [71]. For an average acre of land in the United States, around one-third of the precipitation received is given off to the atmosphere and the remainder will eventually find its way to a watercourse and in the end to the sea. Coastal waters are strongly governed by this runoff and by its chemical and particulate content and rate of discharge. Changing the natural rate or volume of flow by more than 10 percent should be considered unfavorable and avoided wherever possible.

Elimination of pollution in runoff water is a national goal to be accomplished by 1985. Runoff water has been analyzed and may have higher biochemical oxygen demand (BOD) and greater concentrations of various pollutants than domestic sewage [109][110] (Table 25). Sources of contamination include litter, automobile oil and grease, spillage from bulk chemical storage, and exposed dirt piles at construction sites.

Pollution as well as altered runoff flows can be corrected. The basic requirement of a stormwater system is to retain precipitation within

Table 25. Estimated Quantities of Pollutants that Could Enter Municipal Receiving Waters in a Hypothetical City (Source: Reference 111)

ITEM	STREET SURFACE RUNOFF (following 1 hr storm) (lb/hr)	RAW SANITARY SEWAGE (lb/hr)	SECONDARY PLANT EFFLUENT (lb/hr)
Settleable plus Suspended Solids	560,000	1,300	130
BOD_5	5,600	1,100	110
COD	13,000	1,200	120
Kjeldahl nitrogen	800	210	20
Phosphates	440	50	2.5
Total cell form bacteria (org/hr)	4000×10^{10}	$460{,}000 \times 10^{10}$	4.6×10^{10}

the boundaries of the site and to release it at a natural rate and in acceptable quality. The stormwater plan must consider the immediate effects of construction activity as well as the long-term effects of operation of the project. Stormwater retention and water quality restoration from a development site usually involve either (1) artificial detention (basin) and treatment system; (2) an adequate vegetated surface for natural treatment, or (3) some combination of the two strategies. In any event, the system should be designed to hold for treatment and slow release the heaviest normal rainfall expected (the 5-year or 10-year flood).

4.12.2 Conventional Systems

In coastal urban areas, large-scale storm sewer systems often collect runoff and pipe it either (1) directly into coastal waters through a "separate system" or (2) into the municipal wastewater treatment plant through a "combined system" of stormwater and wastewater. On the one hand, the direct discharge (no-treatment) alternative creates high peak flow surges of fresh water, that contains pollutants, to the coastal basin with adverse effects on the ecosystem. On the other hand, the combined treatment alternative often leads to flow surges that overwhelm the treatment system resulting in discharge of raw sewage and stormwater to the coastal basin.

Combining the stormwater and sewage systems for convenience and economy is not usually acceptable. They are generally not capable of handling the combined load during runoff surges. Also, the treatment required for sewage may be quite different from that required for stormwater. The best solution is to build separate systems to perform the two functions and optimize each for its specific purpose. Modification of existing systems to achieve separate stormwater treatment is difficult and very expensive. In either expansion and rehabitation of old systems or planning for new systems, substantial savings may be realized by designing the separate stormwater system to treat only the initial, highly polluted first flush increment of runoff--the first half inch or so which contains most of the pollutants. For example, over 85 percent of the BOD may occur in the first one-third to one inch of rainfall [112].

Storm runoff alone is often severe enough to drive the coliform count above the national health standard of 70 MPN (most probable number per 100 ml. of sample water). For example, on Long Island, New York, local officials now believe that, despite plans for a billion-dollar sewage treatment plant, productive shellfish beds will remain closed because of bacterial contamination from urban runoff alone [113].

4.12.3 Industrial Sites

Storm runoff from heavily industrialized sites, such as those occupied by petroleum refineries, and petrochemical plants, contains quantities of wastes not found in urban areas. In one study, runoff from industrial areas contained 2,800 pounds of contaminants per road curb-mile. Residential areas, on the other hand, contributed 1,200 and commercial areas 290 pounds per curb-mile [71].

Significant amounts of toxic matter should not be allowed to run directly to coastal waters, nor should such matter go into the sanitary sewer system. The presence of toxic metals in industrial runoff poses a special treatment problem, as their presence can reduce BOD removal by killing bacteria in the activated sludge, anaerobic digestion, and nitrification-dentrification types of sewage treatment. Special management is required for these sites, which may include separate collection and treatment. The problems often can be mitigated by installing an on-site treatment plant to remove contaminants. This may be required by the EPA in some cases, including gas processing plants and oil refineries [114].

Economy in runoff treatment for an industrial site with an appropriate land form and surface character may be accomplished through "land treatment" by discharging runoff onto a specially designed vegetated slope [115]. The soil and vegetation filter and recondition the water as it flows over the slope to a collecting channel at its base.

4.12.4 Artificial Detention

An alternative to control storm sewer systems that is often feasible is to collect stormwater in dispersed detention facilities and delay its release to approximate the predevelopment rate of flow as closely as possible. Detention facilities should be of sufficient capacity to absorb the maximum amount expected and, where possible, stormwater should be introduced into the soil for reconditioning.

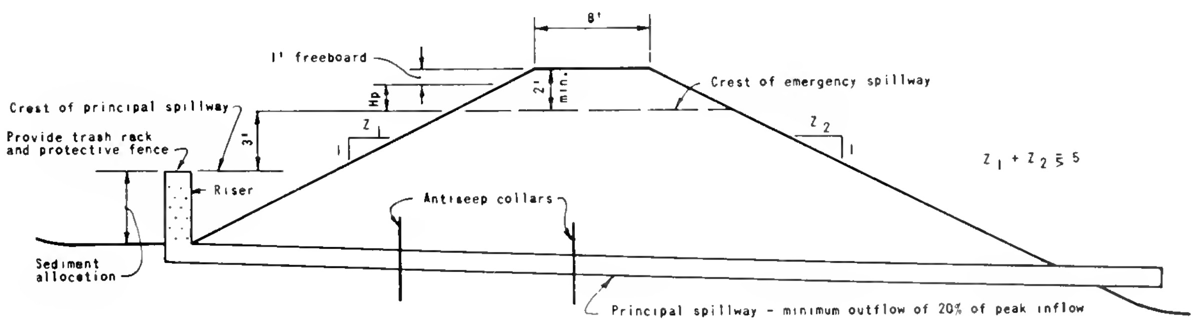
There are many design techniques for detaining and returning rainfall to the soil, based on collection of water and seepage through gravel into the groundwater. Runoff can be held on-site in any combination of the following:

1. Runoff detention ponds
2. Gravel-filled ditches
3. Gravel-filled seepage pits.

A combination of runoff detention ponds with seepage facilities is often successful.

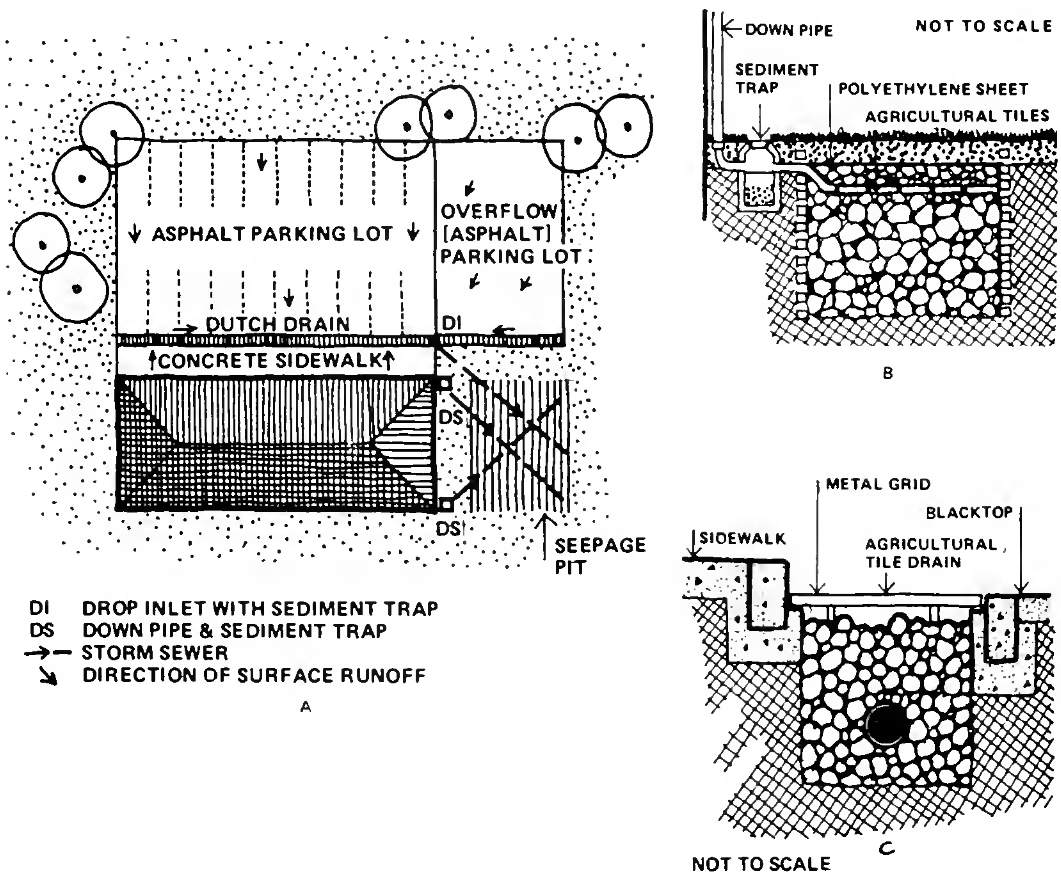
Detention basins (Figure 37), impoundments, or ponding areas make up for the reduction in natural storage capacity caused by devegetation, paving, and buildings [116]. They also allow for sediments and absorbed pollutants to settle out. (Standard urban storm drainage systems are often designed to handle a 25-year storm.)

Figure 37. Large, well-engineered detention pond and sediment basin dam (Source: Reference 70).



Seepage beds, often called "Dutch drains", are gravel-filled ditches that dispose of stormwater by ground infiltration (Figure 38). They can reduce total runoff volume and diminish local flood peaks in any area where soil porosity is at least 0.12 foot per day. Seepage pits and seepage beds are often used together.

Figure 38. Sample infiltration system for runoff water showing the design for (A) receptacle, (B) seepage pit, and (C) Dutch drain (Source: Reference 71).



Like seepage drains, seepage pits are usually gravel-filled structures that collect runoff and allow percolation into the soil (see Figure 38C). Seepage pits, however, hold the runoff long enough to allow filtration before release. As a result, they are more likely to become clogged with sediments than are Dutch drains. A properly designed seepage pit (also called a "dry well") will maintain infiltration at pre-development levels and enhance the local water supply, provided that soil porosity is at least 0.15 foot per day. It can be located centrally in a parking lot or other large paved area; an overflow storage system can be incorporated to use part of the paved area as a detention basin [71].

4.12.5 Simulating Natural Systems

In the natural system, water passes over vegetated land as overland flow or through the soil in the groundwater. Pollutants are removed biologically by microorganisms or plants; physically by filtration, absorption, or deposition; and chemically by oxidation and other reactions. Purification continues in streams and drainage-ways by the same processes. Natural watercourses tend to meander through coastal watersheds and floodplains, thus slowing the passage of water to the sea and allowing greater opportunity for natural purification. Meandering watercourses are also conducive to stream side vegetation, which aids greatly in purification.

The typical stormwater system has been designed to short-circuit the natural process. Runoff water is diverted to drains, then to collection pipes and trunks and finally to outlets that discharge into the nearest watercourse. Natural purification by vegetation and soils is more efficient and far less expensive than by artificial measures.

A stormwater system that simulates the natural drainage system has features to detain storm runoff and provides maximum soil infiltration for natural purification. The ideal way would be to preserve and utilize existing natural drainages such as creeks, sloughs, and swales, and to provide natural buffer strips along the edges of all watercourses [116].

The Soil Conservation Service has summarized techniques available for controlling runoff and thus simulating the natural rate of release (Table 26). Although many of these techniques may be unsuitable for wide application because they are experimental or do not fit local circumstances, they suggest the variety of alternative solutions available.

4.13 SOLID WASTE DISPOSAL - SUBPROJECT 13

In this affluent country, each person consumes an average of 150 pounds of raw material every day, of which 130 pounds is in the form of industrial products. Petroleum products and the factors of production used by the petroleum industry account for a good deal of this industrial consumption, and because much is eventually disposed of as solid waste in landfills, this section highlights the location and design constraints of landfills.

4.13.1 Summary

The major sources of waste may be lumped into three broad categories: municipal waste, agricultural waste, and industrial waste. Municipal

Table 26. Measures for Reducing and Delaying Urban Storm Runoff (Source: Reference 117)

Area	Reducing Runoff	Delaying Runoff
Large flat roof	1. Cistern storage 2. Rooftop gardens 3. Pool or fountain storage 4. Sod roof cover	1. Ponding on roof by constricted down-spouts 2. Increasing roof roughness a. Rippled roof b. Graveled roof
Parking lots	1. Porous pavement a. Gravel parking lots b. Porous or punctured asphalt 2. Gravel beds or cisterns beneath parking lots in high-value areas 3. Vegetated ponding areas around parking lots 4. Gravel trenches	1. Grassy strips on parking lots 2. Grassed waterways draining parking lot 3. Ponding and detention measures for impervious areas a. Rippled pavement b. Depressions c. Basins
Residential	1. Cisterns for individual homes or groups of homes 2. Gravel driveways (porous) 3. Contoured landscape 4. Groundwater recharge a. Perforated pipe b. Gravel (sand) c. Trench d. Porous pipe e. Dry wells 5. Vegetated depressions	1. Reservoir or detention basin 2. Planting a high delaying grass (high roughness) 3. Gravel driveways 4. Grassy gutters or channels 5. Increased length of travel of runoff by means of gutters, diversions, etc.
General	1. Gravel alleys 2. Porous sidewalks 3. Mulched planters	1. Gravel alleys

waste includes residential, commercial, and demolition debris; agricultural waste includes animal manures and crop residues; industrial waste includes excesses from food processing, manufacturing, and lumbering.

Major oil-related facilities and the secondary development induced by them produce large volumes of solid wastes. For example, a refinery produces the following types of solid wastes [118].

1. Varying amounts of iron rust, iron sulfides, clay, and sand in crude oil.

2. Silt from surface drainage into refinery sewer systems, and screened out in wastewater treatment.

3. Silt and other debris from the water supply, screened out prior to use in the refinery.

4. Corrosion from processing units.

5. Spent catalysts, which vary from refinery to refinery in quantity and quality.

6. Sludge, from wastewater treatment, unless incinerated.

Furthermore, the construction of OCS-related facilities, as well as construction of the facilities induced to locate in the coastal zone, also contributes to the volume of solid wastes to be disposed of.

The aim of solid waste disposal processes is to convert the waste to a less offensive form and to reduce its volume so that it can be disposed of more readily. The four primary methods of solid waste disposal are, in order of decreasing usage: landfill, resource recovery, incineration, and ocean disposal.

Groundwater or infiltrating surface water moving through solid wastes disposed of in landfills produces a solution called "leachate", which contains dissolved and finely suspended solid matter and microbial waste products (Table 27). When it enters estuarine areas it introduces toxicants, heavy metals, and pesticides, and causes oxygen depletion [120].

Table 27. Generalized Analyses of Various Liquid Wastes (in Parts Per Million). (Source: Reference 119)

	Landfill Leachate				
Constituents	Less than 2 yrs old	6 yrs old	17 yrs old	Raw Sewage[1]	Slaughter-house[2] wastes
BOD*	54,610	14,080	225	104	3,700
COD†	39,680	8,000	40	246	8,620
Total Solids	19,144	6,794	1,198		2,690
Chloride	1,697	1,330	135		320
Sodium	900	810	74		
Iron	5,500	6 3	0 6	2 6	
Sulfate	680	2	2		370
Hardness	7,830	2,200	540		66
Misc. Heavy Metals	15 8	1 6	5 4	1 3	

[1]Data provided by the Metropolitan Sanitary District of Greater Chicago
[2]Data from the files of the Illinois Department of Public Health
*Biological oxygen demand
†Chemical oxygen demand

If leachate from a landfill is intermittently or continuously in contact with groundwater or surface-water sources, the water becomes polluted [121], with potentially serious consequences. For example, recently landfill leachate has been identified as a major source of polychlorinated biphenyl (PCB) pollution of coastal waters.

Since more than 90 percent of solid wastes are disposed on land in dumps and landfills, this section emphasizes the importance of location and design of sanitary landfills to protect vital habitat areas and to prevent water pollution.

4.13.2 Location

Landfilling of solid wastes at the shore, particularly in wetlands areas, presents a twofold threat. First, it creates the danger of polluting areas outside of the fills themselves through contamination of leachates when water percolates through solid waste, and, secondly, it causes a reduction in wetlands.

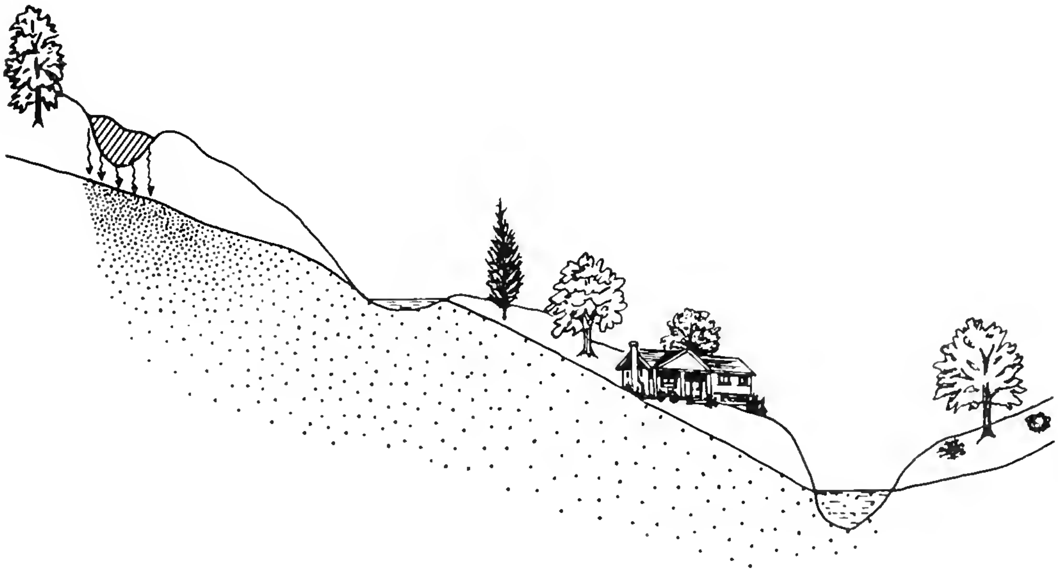
Leachate: Sanitary landfills should be located in areas of suitable water characteristics and soil permeability. To avoid leachate pollution, the landfill should be located well above the groundwater table, where soils are of optimum permeability and texture. At the minimum, a distance of 10 feet between the lowest layer of deposited refuse and the seasonal high groundwater table should be maintained to provide sufficient protection of groundwater quality [122].

Landfill sites should always be out of the path of natural drainageways, above the lower coastal floodplain (above the 10-year flood level), and away from surface water bodies. A minimum distance of 1,000 feet from surface water and 1 mile from municipal wells is recommended [122].

The movement of leachate from a waste disposal site is governed by the physical environment (Figure 39). When the wastes are deposited above the water table, both chemical and biological contaminants in the leachate move downward through the surficial soils (zone of aeration) at a rate dependent in part on the properties of the soils. The chemical contaminants, being in solution, generally tend to travel faster than suspended biological contaminants. Particulate biological contaminants are largely filtered from the percolating leachate. The chemical contaminants, however, may be carried rapidly by the leachate water to the water table. The potential for water pollution depends on the mobility of the contaminant, its accessibility to the groundwater reservoir, and the hydraulic characteristics of that reservoir [123].

In areas of high rainfall, the pollution potential from leachates is greater than in less humid areas. In semiarid areas there may be little or no risk of pollution because all water is either absorbed by the refuse or is held as soil moisture and is ultimately evaporated. In

Figure 39. Cross-section showing leaching from an improperly designed sanitary landfill (Source: Reference 123).



areas of shallow water table, where refuse is in constant contact with the groundwater, leaching is a continual process, producing maximum potential for groundwater pollution [123].

Wetlands: Wetlands disposal once seemed logical because such space was cheap, available, and normally thought of as "wasteland". This attitude has since changed, however, because of the recognition of marshes, bogs, swamps, and other wetlands as vital habitats essential to the proper functioning of natural water systems.

In addition to their direct loss from filling with solid wastes, wetland and lower floodplain dump sites have high potentials for causing water pollution. In wetlands there is a high rate of leaching of toxic chemicals, nutrient chemicals, and suspended organic matter from the town dump into the groundwater, as well as washoff of the same pollutants during rainstorms and flooding.

4.13.3 Design and Maintenance

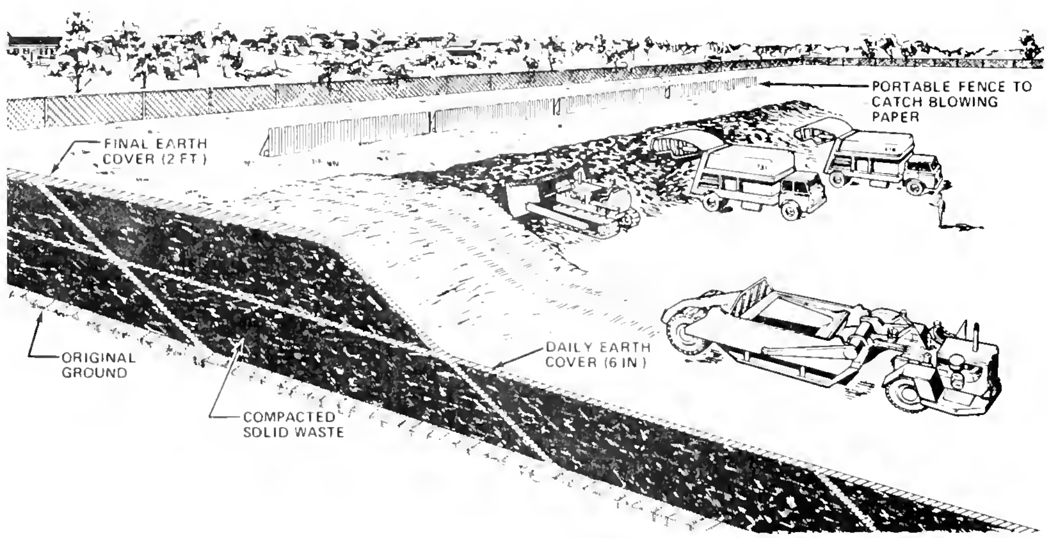
Modern engineering techniques allow the control of both leachate production and its movement away from the landfill site. This is accomplished by reducing the amount of surface water and groundwater entering the fill area to the minimum and controlling the leachate runoff from the fill. To safeguard against leachate infiltration of the groundwater, clay (or a suitable equivalent) should be used to seal the walls and bottom of the prepared fill site [124].

In many cases poor landfill or dump siting has created severe water pollution problems because refuse was deposited in the path of surface-water drainage flows. In existing situations of this type, management of surface-water flow is necessary to minimize runoff into and out of the deposited waste. When there is serious existing leakage of contaminant, the polluted groundwater to be treated should be intercepted as near the fill site as possible, before it causes widespread contamination of the aquifer and pollutes the surface bodies that it enters.

Existing landfills with pollution problems that are not correctable in any practical sense should be identified as nonconforming uses and either removed or sealed up and properly revegetated at the earliest opportunity.

Other management techniques can lessen the environmental impact of a landfill site. For example, a daily cover of six inches of earth should be applied to reduce odor, windblown debris and hasten the restoration of the landfill site for other uses (see Figure 40). The detoxification and drying of the solid wastes can also be enhanced by planting cover (e.g., pines and suitable brushes) [126]. This is the most rapid way to restore a landfill to productive uses.

Figure 40. A typical municipal landfill (Source: Reference 125).



4.14 INDUSTRIAL WASTEWATER SYSTEMS - SUBPROJECT 14

Process wastewater from industries sited in coastal areas have potential impacts that range from relatively minor disturbances to major disruptions caused by excessive discharge of toxic chemicals.

Oil spills and other catastrophic releases often have prominence in the public eye, but perhaps a more damaging form of pollution is the chronic release of industrial contaminants that insidiously degrade coastal ecosystems. There may be no large fish kills or other dramatic evidence of harm, but only a pervasive and continuous degradation of the system manifested by an apparent and somewhat mysterious decline in its carrying capacity. Industrial waste materials in plant effluents may alter carrying capacity of the coastal ecosystem in a variety of ways.

4.14.1 Summary

This section is concerned with routine discharges of process wastewater from OCS-related industries; mainly from refineries, petrochemical plants, gas processing plants, and partial processing plants. It does not deal with accidental releases or spills. (Oil spills are treated in Section 4.19; cooling water in Section 4.15; sewage in Section 4.10; and stormwater runoff in Section 4.12).

Industrial wastewater which contains chemicals added in the treatment processes or contaminated with material being processed is referred to as process water. Process water from the facilities which support OCS activities contains oil and oil-coated solids. In addition, the electrical method of crude desalting produces wastewater containing sulfides, suspended solids, phenols, and ammonia, all at higher temperatures. Crude oil fractionation produces sulfides, chlorides, and phenols. The thermal cracking process, hydrotreating, lube oil finishing, and other operations produce wastewater containing phenols, oils, sulfur compounds, ammonia, and stable oil emulsions [127].

The quality and volume of wastewater discharged will depend upon the physical and chemical characteristics of the product's rate of processing, plant design and complexity, and the degree of treatment of effluent.

Particular characteristics of aquatic ecosystems govern their capacities to absorb impacts. The probability that pollutants discharged into any water body will accumulate to damaging levels is controlled by water basin configuration. The contamination potential of a water body is a function of its capacity (length, width, and depth) and the rate of exchange (flushing) of its waters. These factors control the rate of dilution and dispersion of the contaminant and its biological and physical storage.

Substances are termed "toxic" when their physical or chemical properties interfere with normal biological functions. The interference can occur at any level of the ecosystem. When released in a concentrated manner at a defined point, contaminants are called "point-source" pollutants.

In 1972 Congress established as a national goal the elimination of all discharge of pollutants into navigable waters by 1985. On or before July 1, 1983, water quality standards must be applied that provide for the protection and propagation of fish, shellfish, and wildlife, and that allow for recreation in and on the water. Permitted discharges for an oil refinery, for example, are shown in Table 28. Currently,

Table 28. Permitted Current (A) and 1983 Projected (B) Effluent Discharges (in Pounds per Day) for a 250,000 BBL per Day Refinery (Source: References 7 and 8)

(A)

Fuel Mix	Low		High	
	Daily max.	30 day avg.	Daily max.	30 day avg.
BOD (5 day test)	1,675	900	1,175	655
Total Suspended Solids	1,000	575	725	410
COD	12,000	6,075	8,475	4,300
Oil & Grease	500	270	348	190
Phenol	12.3	5.75	8.5	4.0
Ammonia (as N)	1,900	875	1,350	613
Sulfide	10.8	5.0	7.5	3.5
Total Chromium	24.3	14.3	17.3	10
Hexavalent Chromium	5.25	2.35	3.75	1.65
pH	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0

(B)

Fuel Mix	Low		High	
	Daily max.	30 day avg.	Daily max.	30 day avg.
BOD 5	348	285	245	203
Total Suspended Solids	348	285	245	203
COD	1,975	1,550	1,400	1,100
Oil & Grease	70	55	50	40
Phenol	1.6	1.13	1.13	.80
Ammonia (as N)	463	348	328	245
Sul. de	7.5	5.0	5.3	3.5
Total Chromium	16.8	14.3	11.8	10
Hexavalent Chromium	.38	0.23	0.28	0.16
PH	6.0-9.0	6.0-9.0	6.0-9.0	6.0-9.0

industrial, municipal, and other point-source dischargers (including OCS-related industries) must obtain permits for the discharge of any pollutants into the navigable waters of the United States under the National Pollution Discharge Elimination System (NPDES). Point-source pollutants may have profound effects on coastal ecosystems and should be considered in relation to siting, design, and operation of OCS-related onshore facilities.

Disposal of liquid wastes into the estuarine environment is the major pollution impact on coastal waters. This problem can be solved either by treating all wastes to such an extent that they do not alter the ecosystem or reduce the carrying capacity, or else by entirely prohibiting their discharge into the environment.

Technology exists for the effective treatment of nearly every kind of municipal and industrial waste. Treatment requirements for different wastes may vary from place to place according to local conditions.

Water quality standards have been set by EPA and are being implemented in all coastal states. These standards and stringent effluent limitations are the foundations on which the effective control of estuarine pollution rests, and they provide the framework within which technical management can effectively operate.

4.14.2 Discharges

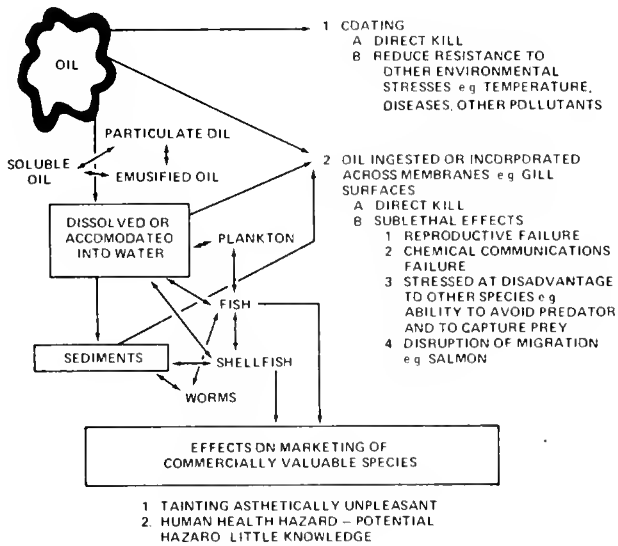
Each class of OCS-related facility (oil refinery, gas processing plant, etc.) is characterized by a general family of potential polluting residuals. Yet, no approximation of the actual discharge of residuals can be made until the design and working characteristics of the individual plant are known in detail. For example: [7]

> The concentration of pollutants in the refinery effluent will vary as a function of the complexity of the refinery's processing range from simple crude oil separation by distillation to more complex alterations involving rearrangement of chemical structures.... When heavier crude oil is refined...COD concentrations are higher than when refining lighter crude oils. There appears to be no meaningful correlation between feedstock and raw waste load for... BOD, total suspended solids, oil and grease, phenol and ammonia.

Several major classes of pollutants typical of OCS-related industrial process waters are discussed in the following paragraphs.

Hydrocarbons: Process water discharges from OCS-related facilities may contain a variety of hydrocarbons in sizeable quantities. These include oil and grease as well as cresol, phenol compounds, kerosene, naphtha, styrene, and toluene. These substances are incorporated into coastal ecosystems through many pathways (Figure 41) and have a wide variety of impacts on estuarine systems. These impacts, aside from obvious aesthetic effects, range from immediate smothering to chronic, subtle genetic modification of marine organisms. In addition, oils act to concentrate other pollutants, such as pesticides (particularly chlorinated hydrocarbons), thereby increasing the ecological hazards. Estuarine systems are vulnerable to extreme effects from petroleum because of bioaccumulation through the food chain.

Figure 41. Pathways of oil incorporation into marine ecosystems and effects on marine life (Source: Reference 128).



The potential threat of carcinogenic petroleum substances transmitted into the human food chain from contaminated seafood products remains to be scientifically demonstrated. The rates of transfer and long-range fate and effect of water soluble components of petroleum are also poorly understood.

Heavy metals: Heavy metals discharged by OCS-related facilities include beryllium, cadmium, chromium, copper, lead, mercury, nickel, silver, vanadium, and zinc [7]. Their salts are relatively soluble and stable in solution; consequently, they will persist for extended lengths of time. The presence of these metals from industrial waste discharge, even in small concentrations, can have deleterious effects [84], primarily because of biomagnification.

In order of generally decreasing lethality to aquatic organisms, mercury, silver, and copper are at the top of the list, followed by cadmium, lead, chromium, nickel and cobalt [129]. Although the sediments can sometimes act as a sink for entrapment of metals, activities such as dredging often release metals back into the marine ecosystem, potentially contaminating fisheries' resources and possibly entering the human food chain.

Biochemical Oxygen Demand (BOD): One of the major constituents of industrial wastes related to hydrocarbon processing is decomposable organic material. These substances take up dissolved oxygen from the water as they decompose, often causing the oxygen concentration of the water to fall to a level that is adverse to aquatic life. BOD is a measure of the oxygen depletion potential of organic matter introduced into a water body (in pounds of oxygen consumed). Occasionally, animals are killed by a sudden oxygen drop, but the usual effect is to impair their health, or, if they are mobile, to drive them away. An example is the blockage of fish spawning migrations in the Delaware River, where greatly reduced oxygen near Philadelphia (from combined sewage and industrial effluent) appears to have now eliminated striped bass spawning.

The level of dissolved oxygen is one direct index of the health of the system. High levels are generally indicative of a healthy system that will support a diverse biota and multiple uses. The lower the concentration of dissolved oxygen, the lower the potential carrying capacity of the system becomes [84].

Dissolved Solids: This water quality parameter is the "filterable" component of water chemicals and including the carbonates, sulfates, chlorides, phosphates, and nitrates. The quantity and quality of dissolved solids are major factors determining the variety and abundance of plant and animal life in the aquatic system because they include the primary nutrients.

4.14.3 Assimilation Capacity

The effect of pollutants on the estuarine environment depends on how strong they are, where they go, and how rapidly they are assimilated or flushed out of the environment. All of these conditions depend on water movement and circulation patterns, which are in turn governed by the relationship of tide and river flow to estuarine basin shape and size [84].

Active circulation and a good rate of flushing are usually considered beneficial because they provide rapid transport of nutrients and cleansing of the natural system, as well as performing other vital functions. To an extent, good flushing protects ecosystems stressed by development because it hastens the assimilation, dispersal, and dilution of pollution.

A high proportion of U.S. coastal water basins have poor flushing characteristics. For example, in the Texas gulf,inflows into the major estuaries west of the Neches River are often small, leading to relatively slow flushing of the estuaries. The upper Houston ship channel has an average flushing time of 38 days and a flushing time as great as 80 days over 10 percent of the time. The median flushing period for Galveston Bay is 175 days. This combination of limited tidal mixing and limited freshwater inflow is believed to create "a condition which is particularly susceptible to the buildup of pollutants and, consequently, to a significant impact of these pollutants in the water quality" [130].

Tidal action alone may not rapidly sweep an estuary clean of pollutants. Although estuarine water may be in oscillating motion because of tidal action, the resultant flow may be mostly reciprocal, rather than directional, and the process of discharge to the ocean may be slow in non-stratified estuaries. Clearly, in predicting the effects of pollution it is important to recognize that different types of water bodies are characterized by different assimilative capacities.

Industrial facilities that cause heavy pollution, such as petrochemical plants, may have to be banned from confined estuarine waters. Moreover, todal creeks, dead-end harbors, small lagoons, and similar small or poorly flushed water bodies should be off limits for all discharges because of their extremely limited capacity to accept and assimilate even small amounts of contaminants.

Physical and chemical characteristics of the water itself (temperature, DO, suspended solids) will affect the chemical reactivity of pollutants such as heavy metals and ammonia, and will determine to a large extent the chemical composition, solubility, and retention time of such pollutants in the receiving waters. Pollutants in the water in certain concentrations may react synergistically, causing a greater impact than if each had acted separately. Such effects have been observed for combinations of temperature and oxygen stress and mercury intoxication [131] [132]. There are many such synergistic effects, involving combinations of pesticides, detergents, heavy metals, PCBs, pulp mill and sewage waste, petroleum products, radioactive substances, thermal pollution, and dredged material. Such complex matters are considered in impact assessment.

Ranking Basin Waters: It is necessary, in conformance with the planning requirements of the EPA, for each state to classify and rank basin waters according to severity of pollution. This procedure entails delineating and classifying water segments through a process involving assimilative capacity determination, and ranking them in the order of the severity of pollution problems associated with each.

A water segment is defined as a portion of the basin where surface waters have common hydrological characteristics, common physical, chemical, and biological aspects, and thus, similar reactions to pollutants. These segments are to be classified according to whether or not it is anticipated that water quality objectives will be met after application of 1977 effluent limitations established by the EPA. "Effluent limited" segments are expected to meet the criteria, whereas "water-quality-limited" segments would not.

4.14.4 Treatment

Treatment methods vary as widely as the types of processing that exist in OCS-related industries and the diversity of the products manufactured.

The probable effectiveness of the plan for process water waste treatment for any OCS-related facility depends upon such a complex of factors that it is not feasible to discuss them here. Each facility is a special case. Nevertheless, the following description of refinery waste treatment provides some idea of the systems used [133]:

> By segregating waste water streams within the refinery, optimum treatment can be obtained by preventing massive dilution of waters that require treatment. All waste water, including rain water, leaving the refinery is divided into five separate systems: 1) high solids, non-oily process waters (water treating plant and boiler blowdown); 2) low solids, non-oil water (roads and general area storm waters); 3) oil waste and process area storm water; 4) salt water waste; and 5) sanitary waste.
>
> Some of the process water (1 above) is run through an in-plant water treatment plant before release to the disposal system. Treatment consists of: (1) stripping of sour water; (2) co-mingling and treating of spent caustics for organic acid separation and neutralization of the salt water phase, and (3) recycling of phenolic waters to the desalter for phenol recovery. Water issuing from this plant that requires no further treatment is called clear stream water and can be returned directly to the river stream from which it came.
>
> Oily waste water flows with process area storm water (3 above) through a separator at an average flow rate of 1,050 gallons per minute. As a safety measure to prevent any oily material from escaping, each of the three bays in the separator can handle a thousand gallons per minute (gpm) flow. Two bays having a capacity of 2,000 gpm are in operation at all times, with the third available as a spare. The oil is removed by two adjustable-slot oil skimmers and one rotary drum oil skimmer and returned to the refinery for processing. Trash and most of the suspended solids are also removed here.
>
> The effluent from the separator will be co-mingled with sanitary waste, adjusted for pH as required and pumped to the air flotation unit for secondary treatment. Here the effluent is coagulated to insure recovery of residual oil. Floating and bottom sludge is pumped to the sludge pond for de-watering.
>
> The air flotation effluent goes to the reuse pond where it may either be pumped as part of the makeup water to an induced draft, cross-flow cooling tower or it will be passed on to the oxidation pond from whence it is discharged. The oxidation pond is equipped with a floating oil skimmer to remove any oil that may have been accidently introduced to the effluent.

4.15 INDUSTRIAL COOLING WATER SYSTEMS - SUBPROJECT 15

OCS-related facilities, in which the use of cooling water and its associated environmental impacts are of major importance, include (1) gas processing and LNG plants, (2) refineries, (3) petrochemical plants and (4) power plants dependent on OCS facilities. Impacts associated with extraction of cooling water from surface water bodies include impingement and entrainment of aquatic organisms, contamination of the cooling water by a variety of chemicals, and thermal effects associated with the higher temperature of the discharged cooling water (Figure 42).

4.15.1 Summary

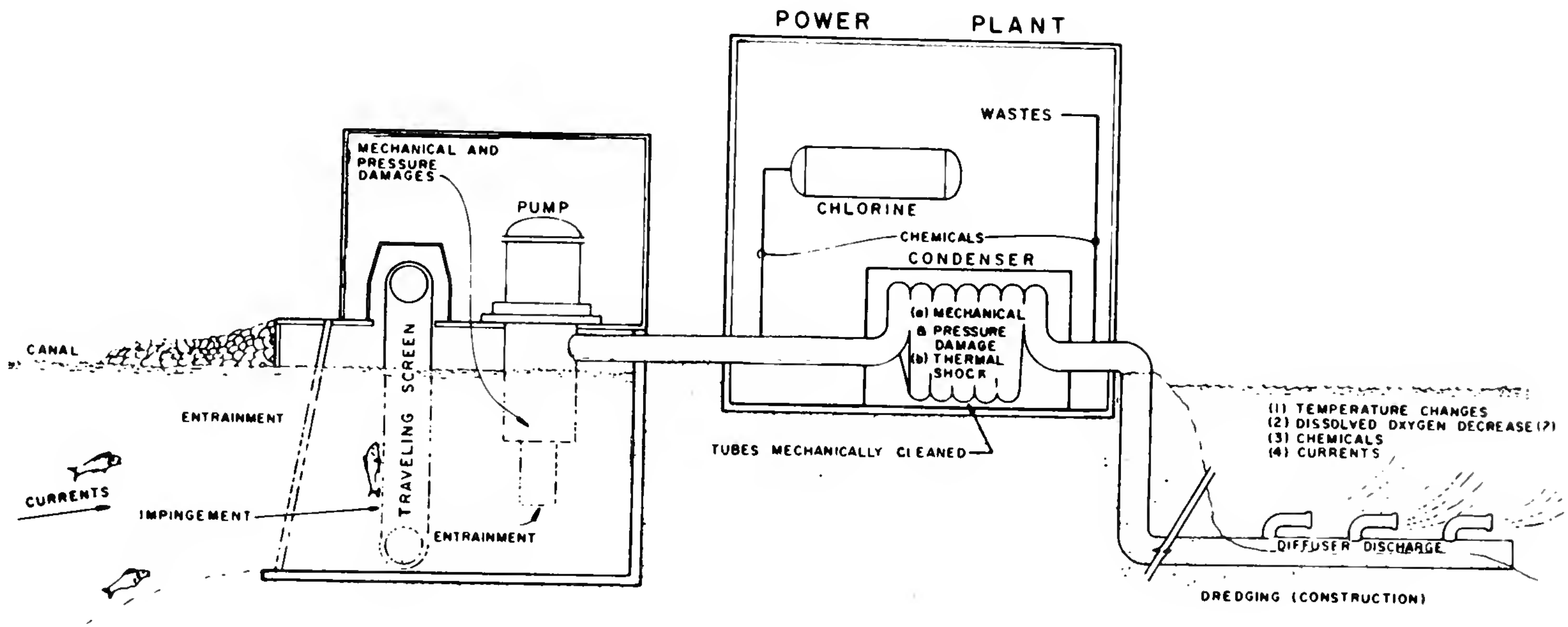
A variety of water uses are associated with OCS-related activities. The most important byproducts, from the standpoint of damage to fish and wildlife and their habitats, are cooling and processing waters.

Since the cooling system is an integral part of the physical plant system, and construction activities are relatively minor threats to the environment, this section focuses on the operational aspects of the cooling water system.

Waste heat from a variety of processes is removed through the use of water or air cooling. Water cooling is preferred because of the high costs and large energy demands required for air cooling. Perhaps 40 percent of the total water use in OCS-related processing industry (70 to 95 percent in gas processing plants) is for cooling purposes [7]. Also, electric power plants generating power for OCS facilities consume massive amounts of cooling water and thus create an extremely high potential for adverse effects in coastal waters. Because most electricity will be purchased from a local utility (except in remote areas), the effects on the cooling water system will be at a power plant site, which may not be in the immediate vicinity of the OCS facility. As a specific example, a refinery complex with a capacity of 250,000 B/D will use 100,000 kilowatts [7].

Many problems for the aquatic environment are posed by large-volume cooling systems. The suspended life in natural waters of estuaries and rivers may be injured or destroyed while passing through plant cooling systems. Larger fishes can be drawn against the intake where they may be crushed against the entrance screens (Figure 42.) Plant cooling systems tend to become fouled with algae and plankton forms. The popular treatment for destroying these organisms is flushing with a periodic dose of hypochlorite (chlorine), which destroys most forms of aquatic life.

Figure 42. Schematic representation of the proposed condenser cooling system of a nuclear power station (Shoreham) and sources of potential biological damage (Source: Reference 134).



After leaving the plant, the heated water may adversely affect the natural patterns of life and behavior of aquatic species. This is often called "thermal pollution". How pervasive and damaging this pollution may be depends upon the characteristics of the discharge (e.g., temperature, volume) and the size and flushing characteristics of the public water basin that receives the effluent.

Since organisms can be filled by impingement on the cooling water intake screens, by passage through cooling water systems, or by heated effluent, specific requirements are imposed on the volume of cooling water, the temperature of the discharge, and the location and design of the intake and discharge structures.

Intake structures may impinge on ecologically vital areas (particularly in estuaries) and cooling water may draw from or discharge into them. Cooling water should not be withdrawn or discharged into vital areas. Their locations should be known from biological surveys that precede site selection for the plant.

4.15.2 Intake Design and Operation

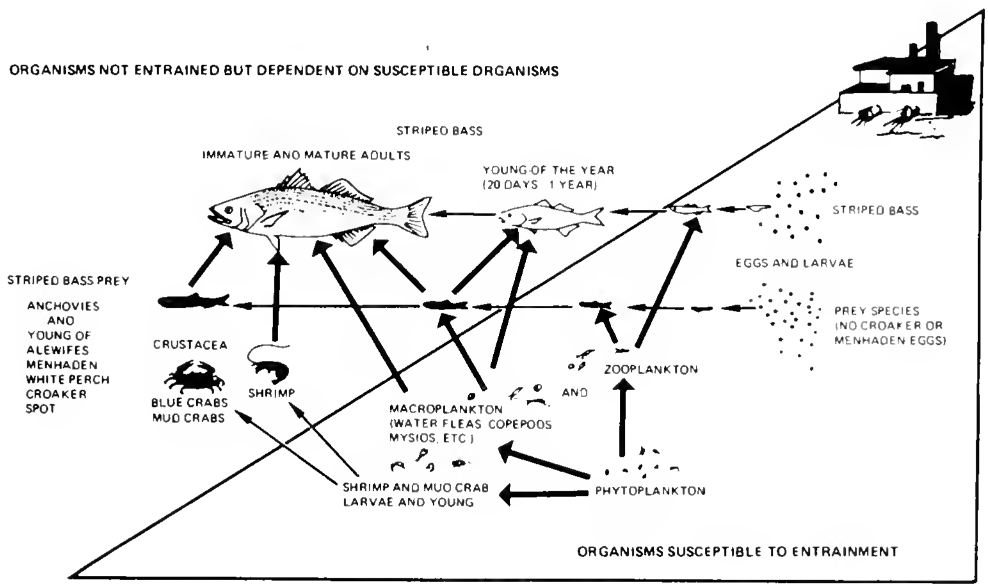
Cooling water systems require close scrutiny, regardless of volume of flow. On the one hand, those with a very low volume demand and need for chemical antifouling treatment may be acceptable without major safeguards. On the other hand, those with a high volume demand or extraordinary requirement for chemical treatment may be acceptable only with extensive safeguards such as closed-cycle cooling or mechanical cleaning.

Power plants have such extraordinarily high demands for cooling water--one million gallons per minute is not uncommon--that they must be reduced by requiring closed-cycle systems, which recirculate cooling waters, rather than open-cycle (or "once-through") systems, which continuously withdraw and discharge large volumes of water. Open-cycle systems may be acceptable for sites on the open ocean coast provided that necessary precautions are taken. Normally, closed-cycle cooling should be used for sites on confined estuarine water bodies such as tidal rivers, bays, or lagoons.

Entrainment, often the major shource of disturbance associated with cooling water taken from surface waters, refers to withdrawal of suspended aquatic life with the cooling water and their exposure to heat, turbulence, abrasion, and shock within the heat exchanger. The effects are especially direct and severe when plants are located in estuarine spawning and nursery areas of finfish and shellfish because their eggs, larvae, and juvenile stages are easily killed. Plankton face the same hazards from passage through an OCS facility, such as a refinery, as they would through a powerplant.

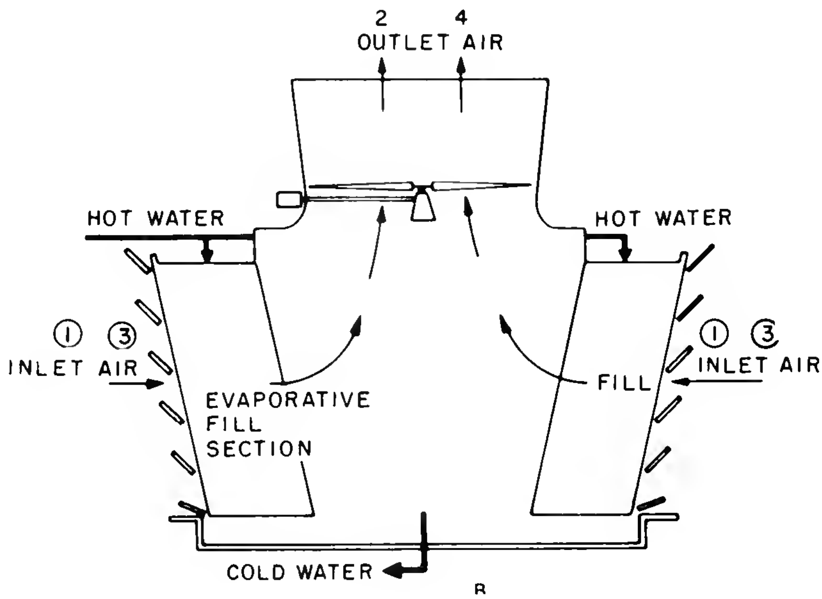
Although plankton appear to better withstand passage through cooling systems, mortalities of entrained zooplankton have been reported to vary from 15 to 100 percent, depending on the size of the organisms [134]. It is important to protect plankton because they supply basic nourishment for the whole chain of life in the estuary and because the young, larvae, and juvenile stages, of valuable finfish and of shellfish are part of the plankton (Figure 43).

Figure 43. Potential power plant impacts on striped bass and associated food items (Source: Reference 136).



Solutions to the problem of entrainment are (1) avoidance of vital areas when locating the intake structures, and (2) reduction of the volume of cooling water by using closed-cycle systems. A closed-cycle cooling system may be costlier than a once-through system but it greatly favors long-term environmental protection. Advanced engineering has produced satisfactory closed-cycle cooling systems that utilize only two to four percent as much water as is used by fully open-cycle systems; consequently, the closed-cycle alternatives consume only 1/25 to 1/50 of the marine biota consumed by once-through plants. Another advantage is that they also discharge a similarly small fraction of heat into public waters. Closed-cycle systems may have natural draft cooling towers, forced (mechanical) draft cooling towers, cooling ponds, or spray canals (Figure 44).

Figure 44. A mechanical draft cooling tower for power plant closed-cycle condenser cooling (Source: Reference 137).



Aquatic animals too large to pass through intake screens (3/8" mesh on power plants) are "impinged on the screening and if the flow rate is high they are unable to escape and will be killed. This problem is associated mostly with the large volumes (over 100,000 gallons per minute) and rates of flow (over 0.25 ft/sec) that are typical of electric power plants [138]. Larger fishes appear to be capable of avoiding entrainment and screen kills are mostly the smaller fishes, less than 5 inches. The number of fishes impaled on power plant screens has exceeded five million in a few weeks' time at one estuarine-sited power plant with open-cycle cooling [138]. Where impingement problems are anticipated, they can best be offset by locating intakes away from gathering areas of small fishes and by eliminating canals, intake bays, forewells, or other containing structures ahead of the intake that would attract fish [138].

If the demand for cooling water is modest, it may be practicable to obtain it from wells or from municipal water systems. New refineries near estuaries should use brackish water but be designed to avoid its corrosive effects. When water is to be supplied by underground wells, the reservoir capacity must be known and withdrawal controlled to avoid excessive losses from groundwater supplies. The lowering of the water table could cause land subsidence or induce saltwater intrusion into the groundwater system in estuarine and oceanic areas.

4.15.3 Discharge Design and Operation

Heated effluent may adversely affect the natural patterns of life and the behavior of aquatic species. How pervasive this thermal pollution may be and how damaging depends on the temperature, volume of output, and size and flushing characteristics of the water basin. Thermal discharges can alter the chemical nature of receiving waters in many ways. Solubility of dissolved oxygen, toxicity of heavy metals, and metabolic rates of aquatic organisms are affected by changes in water temperatures [7]. Injury to organisms is dependent upon a variety of actors, including ambient water temperature, biocide dosage, previous thermal history, physiological state, organism size and life stage.

The influence of heat on the stationary elements of the ecosystem is often far simpler to detect than that of mobile elements. Studies on aquatic animal and plant life have typically shown adverse effects in the vicinity of the discharge plumes of plants with open-cycle cooling. Thermal pollution from industrial cooling discharge is not so much the leading cause of damage to aquatic ecosystems as was once believed. If the heat builds up in a confined area of water, one can expect localized loss of life which may be accelerated in summer by thermal shock and the synergizing effect of temperature on mechanical or chemical factors. The following general guidelines are applicable to estuaries of the Mid Atlantic [138]:

Discharge Temperature (F)	Effect on Zooplankton
80	Death or damage to a high proportion of the more sensitive species.
85	Mortality and high damage to more sensitive species; significant but lower for more resistant species.
90	Widespread high mortality and damage to all but the more resistant species.
95	Nearly complete mortality among most species.

Chemical Contamination: Substances are periodically added to cooling water as it passes through the plant to reduce scaling, corrosion, and the growth of fouling organisms. The antifouling chemicals are often extremely toxic to aquatic organisms in the receiving waters. Typical chemical concentrations of the cooling waters of refineries and gas processing plants are [7]:

Chemical	Concentration Maintained
Sulfuric Acid	Variable*
Chromate	30.0 ppm (5-20)*
Zinc	3.0 ppm (1-4)*
Chlorine	0.1 - 0.2 ppm

* to maintain a pH of approximately 7.0

Concentrations of these substances can be lowered by treatment, e.g. chrome reduction and precipitation using ferrous sulfate in a reducing pit. The residuals produced from this process, like other hazardous wastes, are disposed of in a landfill site. However, chemicals should be used sparingly in treating the cooling water and should be replaced where possible by mechanical or thermal systems of cleaning.

In refineries, oil and oil products can leak into the cooling water system and contaminate the cooling water. Cooling water, although considered to be "not oily", actually comes in contact with oil due to leaks in heat exchangers. When the leaks are severe, oil concentrations may be so high that the cooling water stream must be treated for oil removal prior to discharge.

4.16 MOSQUITO CONTROL - SUBPROJECT 16

The demand for mosquito control is much greater in areas of oil and gas induced development rather than from OCS-related facilities. General control methods, such as pesticide application, have a high potential for disturbance of marsh habitats. When carefully planned, effective control can be achieved through water management.

4.16.1 Summary

Pest control refers particularly to the control of mosquitoes, the most widespread and most noticed of the nuisance species along the coast. With respect to OCS primary development,mosquito control efforts are limited usually to temporary spraying during severe infestations at the time of construction. Control of biting flies, rodents and other pests is usually in response to localized eruptions. Mosquito control is primarily a function of the secondary development that can accompany OCS facilities. Industrial and housing development in coastal shorelands brings more people within range of mosquitoes and increase the pressure on local government to institute controls.

Saltmarsh mosquitoes are controlled by making saltmarsh habitat unsuitable for breeding or by killing insects directly. In the first method, periodic fluctuations in water levels that enable mosquitoes to breed are eliminated. This is accomplished by filling, so that water never stands on the marsh, by ditching, so that water drains from the surface within 2-3 days, or by flooding, so that water completely covers the marsh during the breeding season [139]. In the second method, larvacides or adulticides are sprayed over the marsh.

Different control techniques cause different types of ecological disturbance. The habitat alteration method may severely impair the productivity and habitat qualities of the marsh if not done properly. The use of pesticides, on the other hand, endangers fish and wildlife directly.

Past practices such as marsh filling or extensive drainage ditching in a grid pattern, both of which have long-term adverse impacts, are no longer considered acceptable methods of pest control. Massive pesticide application on a routine basis is also discouraged. Planned water management programs have begun to be recognized as appropriate control alternatives that provide environmental benefits (Figure 45).

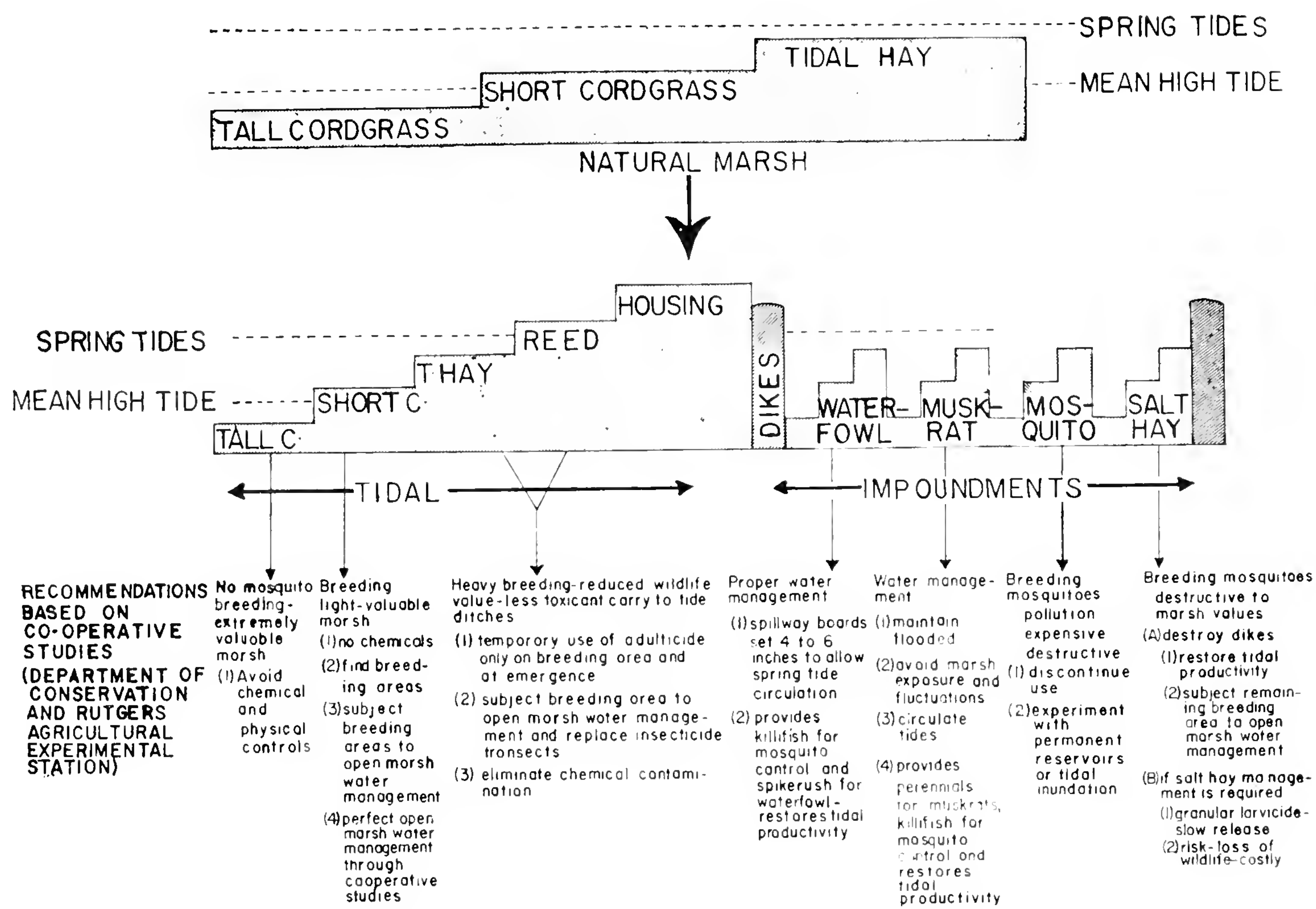
Water level management provides the most effective control of salt-marsh mosquitoes with the least ecological disruption. Water level management may cost more initially than direct control by pesticides, but provides long-term solutions that are not only much better ecologically, but often cheaper over a number of years. In addition to providing effective mosquito control, water management can enhance the flow of water through the marsh, increase marsh productivity, and provide waterfowl habitat.

Coastal wetlands in their natural state are recognized as having high value. The high productivity levels that existed previous to impoundment are difficult to maintain without the normal water level fluctuations and the resultant water circulation and exchange [80].

Diked impoundments cause the same potential disturbances of water flow patterns as flood control dikes and levees. Lower marsh zones and coastal water systems downstream from the impoundment are deprived of freshwater inflow, resulting in changes in salinity, nutrient and sediment balances.

The adverse impacts are likely to be highest when areas are impounded for purposes other than wildlife management. Wildlife impoundments are usually planned and designed to minimize adverse effects. If the

Figure 45. Recommended marsh management for mosquito control based on the ecology of specific marsh elements (Source: Reference 141).



impoundments are used for water supply activities, the drawdowns can create a broad devegetated zone around the edge which is essentially devoid of life and subject to heavy erosion during periods of exposure.

Dikes and levees should contain adequate engineering and management provisions for release of fresh water to streams, floodplains, swamps, and marshes in order to maintain favorable flow and overflow patterns to protect fish and wildlife resources.

Special care should be taken in evaluating the potential effects of levee construction in marshes to ensure that the construction does not lead to dessication of the marsh. Provisions must also be made so that upon abandonment of an area, the levees or dikes are removed in order to restore the area to its former condition [142].

4.16.2 Ditching

Salt-marsh mosquitoes lay their eggs on damp soil under marsh or mangrove vegetation above the mean high water level. Hatching and development is triggered by periodic rainfall or tidal flooding. Reproduction will not occur in the low-marsh areas flooded by daily tides [143].

To rapidly dry up the marsh surface and prevent hatching, the partial draining of high marshes with grid-pattern ditching prevailed as a control method through the 1940's [144]. Such ditching is partially successful in controlling mosquitoes but may be extremely damaging to the marsh ecosystem. Ditching, using plows or trenching machines, creates a network of narrow and shallow channels in the marsh. Dredge material taken out of the ditches typically is deposited on either side of the ditch. Ditching of marshes has been found to be destructive to the existing vegetation and wildlife of marshes. It is the general conclusion that ditching effectively drains the marsh, converting low marsh into a community more characteristic of the high marsh and uplands [145].

As the marsh dries and vegetative replacement takes place, drastic modifications in the animal life of the marsh often occur, including decreases of invertebrates, mostly molluscs and crustacea. The cutting of ditches also permits the intrusion of saline water into regions of the marsh that were formerly brackish or relatively fresh. This adds to the disturbance of the vegetation caused by lowering water tables. Additional impacts are identified where spoil from ditches formed levees which block tidal circulation [140].

4.16.3 Water Management

Water management for pest control consists of an open-marsh water management system of connected ponds and open channels developed to provide access for mosquito-eating fishes and of impoundments created by dikes to maintain stable water levels.

The first method increases mortality by predation during the early life stages; the second prevents hatching.

Open-Marsh Water Management

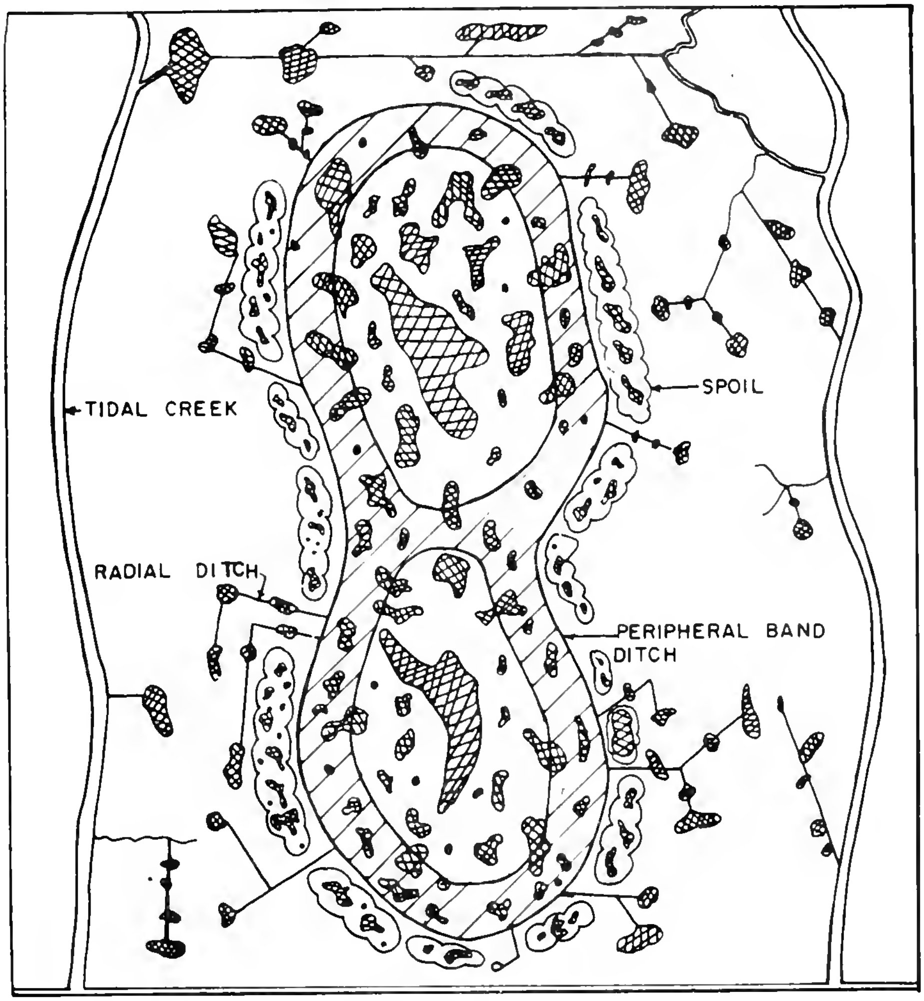
Open-marsh water management for mosquito control is based on a simple natural fact that fish devour large quantities of larvae. Of all possible mosquito control methods, the open-marsh system interferes least with normal wetland function and is recommended as the primary means of salt-marsh mosquito control [146]. The cost appears to be justified by effective, long-term control of mosquito breeding. It requires considerable planning, surveying, and engineering, as well as biological study by entomologists and wildlife biologists [147]. The approach is now feasible throughout most coastal salt marshes although it has yet to be adapted to the mangrove tidelands of Florida.

The open-marsh method is designed to deprive mosquitoes of suitable breeding habitat and increase their vulnerability to predation. When storm or spring tidewaters are retained in isolated pockets (ponds, salt pannes, and other depressions) in the marsh for periods of 4 to 10 days or more, a high potential for mosquito breeding is created. Effective control is obtained by connecting the isolated pockets to the natural drainage system of the marsh with properly designed channels. These provide access to all potential breeding areas for mosquito-eating minnows such as killifish and mosquito fish. The system must also include sufficient deeper, permanent water areas, where fishes can reside during low water periods (Figure 46).

Open-marsh water management has already demonstrated effective control of mosquito breeding without harm to marsh vegetation, while increasing the populations of many important marsh organisms [148] [149]. The connector channels, or radials, also facilitate the transport of suspended organisms and nutrients between marsh and estuary and improve the function of the coastal ecosystem. If constructed correctly, channels are of great value in mosquito water level management because they eliminate the routine need for insecticides, as has been demonstrated in Cumberland County, New Jersey [147].

In open-marsh water management, the channels should be dug only to the depth and width necessary to connect the isolated depressions to the pond-channel system. A rotary ditcher or the equivalent is effective for digging the channels in grassy marsh areas. In reviewing plans for channel excavation, it is important that such machines disperse the channel spoil evenly over the marsh rather than dumping it in piles, which may impede tidal flow [147].

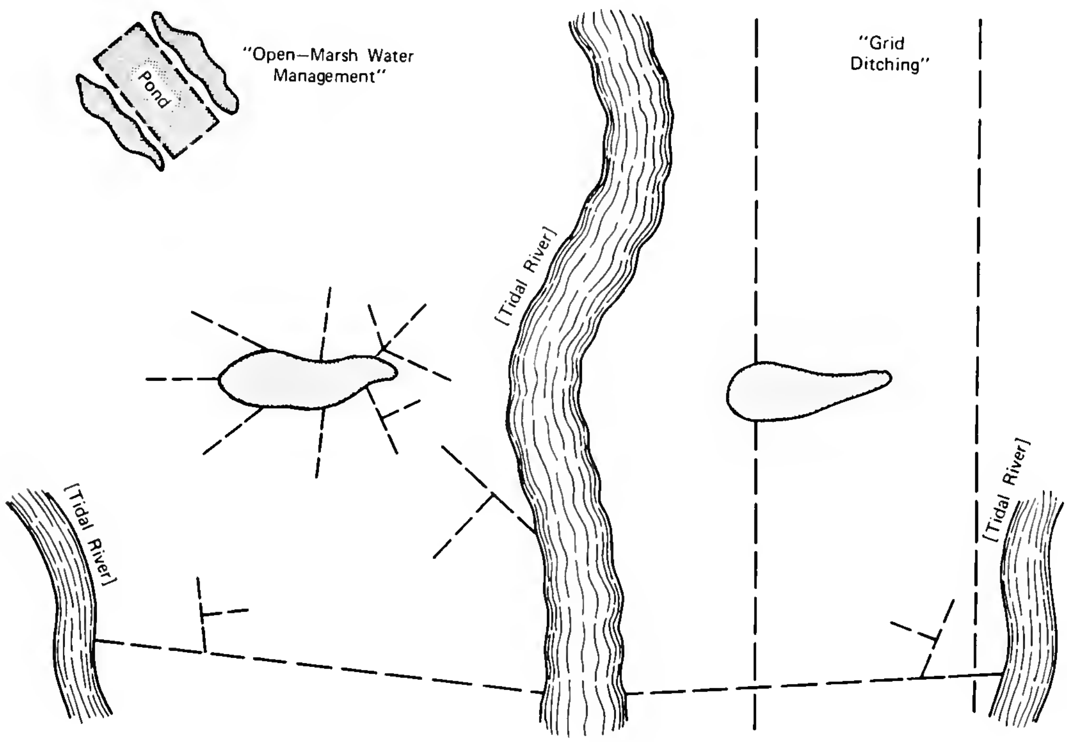
Figure 46. Open-marsh water management plan to eliminate mosquito breeding in depressions (cross-hatched) by building ponds (hatched) and by ditching (Source: Reference 146).



To maintain the water table level, weirs can be built across the channel at strategic heights (between mean high water and mean sea level). A variation of this technique is practiced in Louisiana, where weirs (low dams) are used to hold the water level in tributary creeks and ponds to a minimum depth during neap (low-range) tides. The use of weirs provides for ecological management, boat access and incidental benefits of mosquito control.

The open-marsh approach can be used to rehabilitate thousands of acres of salt-marsh wetlands in many areas of the U.S. that have been seriously degraded by ditching and draining. An appropriate system of connector channels would replace the old ditches, which would be connected to the system only if they are active mosquito breeding areas (Figure 47). Ditches that have silted in and become revegetated would be left to fill in naturally [150].

Figure 47. Example of approved open-marsh water management system for mosquito control (left side) and the outdated grid ditching system (right side) (Source: Reference 150, modified).

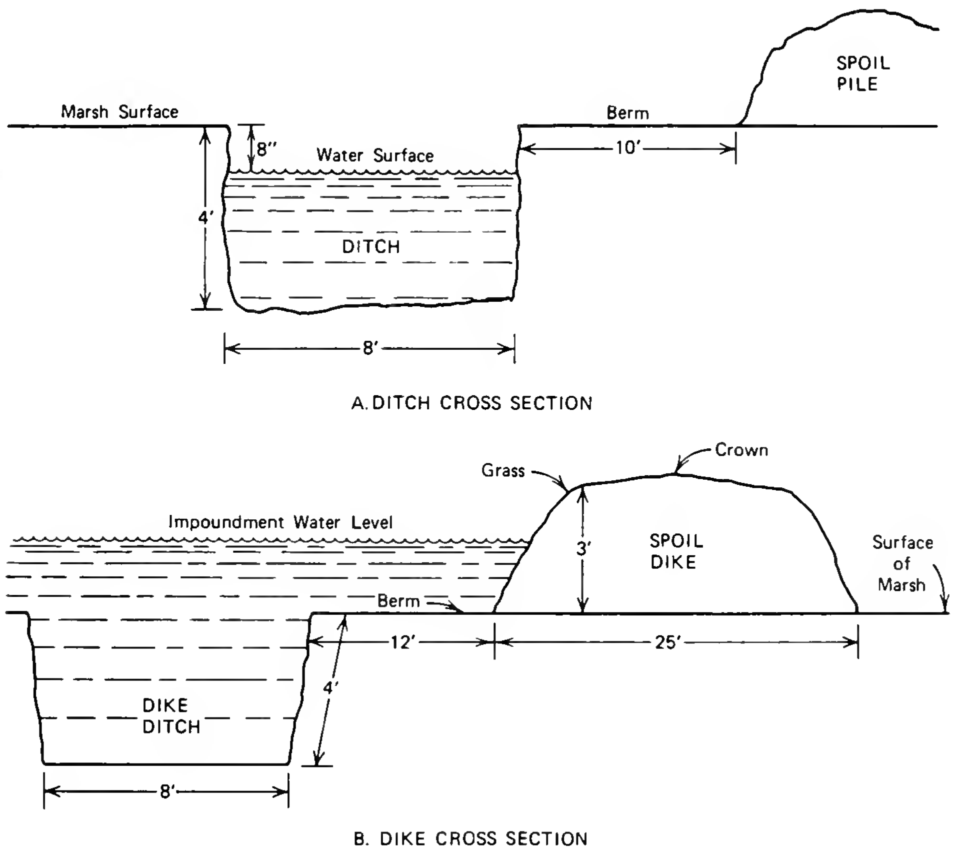


Impoundments

Impoundments for flooding water over a high marsh area not only eliminate the flunctuating moisture conditions required for mosquito breeding, but they also alter the tidal connection which ties the high salt marsh to the estuary. Harmful impacts of marsh impoundments include the loss of important natural areas, the retention of organic detritus which is not released to the estuary, and the inability of estuarine fishes to enter the impoundment for food and shelter.

Because of the adverse effects caused by marsh alteration, impoundment is normally used only in situations where open-marsh management is not feasible. Required ditches and dikes should be properly designed (Figure 48). Impoundments for salt-marsh mosquito control should also be

Figure 48. Schematic of ditch, dike, and impoundment cross sections for mosquito control (Source: Reference 151).



designed for closure only during breeding (warm) months and opened to drying or tidal action during the rest of the year [152].

Although open-marsh water management is generally preferred to impoundments, exceptions occur because tidal conditions may be insufficient to perform the function, or the multiple resource management functions (e.g. waterfowl impoundments) may be planned. Impoundment may be the only environmentally sound option where there is insufficient tidal amplitude (e.g., in the southeastern states) to energize the flow of water through the connector channels of the open-marsh system. Depending on site, design, and management characteristics, an impoundment may enhance the diversity and abundance of birds [153], an important consideration in any impact review of mosquito control plans.

4.16.4 Temporary Control with Pesticides

Limited use of decomposable pesticides for mosquito control may be justified in urgent situations, but the use of pesticides should be limited. Fortunately, between 80 and 90 percent of the salt marshes in the U.S. have not been systematically treated with pesticides for mosquito control [139].

Adult mosquito pesticides are effective for one day, larval mosquito pesticides for several days [154]. Adulticides are applied shortly after emergence, when adult mosquitoes are still concentrated near their breeding areas and before they have dispersed. Ground-level application, typically from truck-mounted foggers, may confine the pesticides closer to the application area than is possible with aerial fogging. Adulticides, however, are the least desirable pest control technique [155]. Larvaciding is generally considered to be more efficient than spraying adult mosquitoes, but caution is required in applying pesticides directly to water because other organisms may be killed.

Products such as Abate (for larvae) and malathion and dibron (for adult mosquitoes) are in common use today. They are believed to be relatively benign and short-lived in the ecosystem [156]. Nevertheless, the misapplication of organophosphate chemicals has been shown to have potentially lethal effects on fishes, shrimp [148], and warm-blooded animals. Oil and surfactant combinations, instead of pesticides, are also commonly used as control agents [157].

Sensitivities of typical estuarine organisms to three major groups of pesticides are shown below (higher numbers reflect greater sensitivity) [158]:

Organism	Herbicide	Organophosphates	Organochlorines
Plankton	1	0.5	3
Shrimp	1	1,000	300
Crab	1	800	100
Oyster	1	1	100
Fish	1	2	500

It is clear that "sensitivities" vary greatly between types of pesticide and groups of fauna [159].

In a toxicity test that included 12 insecticides and seven species of estuarine fish, the descending order of toxicity was as follows: endrin, DDT, dieldrin, aldrin, dioxathion, heptachlor, lindane, methoxychlor, Phosdrin, malathion, DDVP, and methyl parathion [160].

4.17 DIKES, LEVEES, AND IMPOUNDMENTS - SUBPROJECT 17

Dikes and levees are used in coastal areas to direct water flow into or away from a given area. These structures often cause significant disturbances to vital fish and wildlife resources. Once in place, dikes and levees affect both immediate and long-term changes in lowland habitats and adjacent estuarine waters. Solutions to the problem lie in discouraging those land uses in the area to be diked that are incompatible with natural flooding conditions, and limiting the use of dikes and levees as much as possible.

4.17.1 Summary

Dikes and levees are similar types of structures built to hold water either in or out of an area. Constructed levees are linear earthen walls placed most commonly on floodplains on both sides of streams and rivers to prevent high water from flooding the bordering land. Natural berms along riverways are also known as levees. Dikes are embankments constructed of earth or other materials that are often placed across wetlands and tidal creeks to prevent coastal flooding from storms or even daily tidal incursions. Other incentives for construction of dikes and levees are navigation improvement, protection of developed floodplains, creation of suitable acreage for crops such as rice and salt hay, and biological management (mosquito control and waterfowl impoundments). At OCS facilities, dikes may be constructed to contain spoil from associated channel dredging activities and to contain leakage of oil and refinery products from the facility site. As such they are environmental safeguards necessary for the prevention of water pollution.

Major potential disturbances of dikes and levees are obliteration of habitats and the disruption of water flows. These hydrologic changes can trigger profound long-term shifts in salinity levels, nutrient cycles, sediment distribution and, ultimately, the carrying capacity of the system. Dikes used in restoration or enhancement projects may have a net beneficial effect.

4.17.2 Flood Control and Drainage

This subsection deals with earthworks that are constructed for flood control or to assist in land drainage. Levees and dikes built for these purposes involve clearing and grubbing, earth borrow, levee construction, spoil discharge onto wetlands, and in some cases, riprap.

Construction operations involving large earthworks may require extensive excavation of borrow areas, from which fill material is obtained. Borrow areas are generally as close as possible to the site of the levee or dike but they also may be located where there are specific types of fill required for the project. For example, the core area of a levee or of an earthfill dike requires clay so that the structure will be essentially impervious. Since waterborne materials are often deposited in graded sizes, river bluffs, floodplains, and stream bottoms, these areas are frequent locations of borrow activity. When located on uplands, borrow activity involves stripping away the topsoil followed by excavation and hauling of the underlying material. Borrow areas may be quite large, and upon completion of construction, these areas may be contoured and seeded to minimize erosion.

Both spoil from channel dredging and unconsolidated marsh muck are often used for embankments because they are cheap, undesirable for other uses, and immediately available. The solid material in dredge spoil is often composed of silt or organic accumulations which may range to well over 90 percent of the solid material. Once built, these organic levees undergo a loss of over 60 percent of their original height. The reductions in height may result from shrinkage, compaction, edge erosion or ground subsidence [161] [162]. Compaction is a major factor affecting levee height [73]. Stresses can produce cracks or even failure, depending on the load added, the depth of the deposit, and the amount of vertical and horizontal variation within the peat [163].

To retard erosion and subsequent filling of channels, levees exposed to river or tidewater currents are often riprapped with rock or broken concrete.

Potential disturbances to coastal systems by dike and levee systems include: (1) elimination of surface waters; (2) lowering of water table; (3) elimination of periodic flooding and fertilization; (4) reduction of groundwater recharge; (5) increased erosion; (6) more streamflow sent downstream as surge; (7) increased or decreased saltwater penetration; and (8) exposure to deforestation, agriculture, construction, and other human use [142].

The trend now is toward flood management systems that discourage occupancy of floodprone areas,and control land use and construction in ways that protect life and property without reliance on dikes, levees, and other structures. In general, areas that are flooded every few years should be reserved for uses which do not expose life and property to risk or can withstand periodic flooding. The need for dikes and levees as flood control measures can be reduced by prescribing land uses that retain stormwaters in the watershed.

Coastal salt marshes are seriously disturbed by modification of the level of the water table or the rate of surface freshwater flow. A levee placed across the upper end of a coastal marsh has the following primary effects: (1) cuts off all tributaries feeding the marsh; (2) prevents freshwater flooding and fertilization, (3) prevents annual flushing, (4) prevents annual renewal of sediments and nutrients, and (5) ends formation of new marshes [142].

Once leveed and drained, the wetland environment undergoes subsidence resulting from drying,compaction and oxidation, which may lower the elevation as much as a foot per year during the first few years. After initial subsidence, a slower but continual subsidence is evidenced as organic matter in the soil decomposes [142].

About 10,000 acres of tidelands and wetlands diked in southern New Jersey by salt hay farmers became mosquito havens and required the application of pesticides. It is believed that if the diked lands were restored to natural marsh by removing the dikes, 20,000 clapper rails would reside there, and 10,000 black ducks would winter there [150].

Estuarine waters are affected by the changes in water circulation, salinity balance, sediment transport, flushing rate, and natural supply of nutrients from upstream. Such changes affect the physical makeup of the estuarine zone, its energy flows and the plant and animal life, and can create many practical problems. There are examples in Louisiana where fresh water supplies cut off by levees must be replaced by pumping to dilute the salt water sufficiently to discourage marine predators, particularly oyster drills [164].

The presence of dike or levee barriers in "open water" areas across former closely interdependent natural estuarine communities causes long-term changes in migratory fish and shellfish breeding and feeding access, in water flow, and in the basic food web structure and productivity characteristics of the ecosystem.

4.17.3 Impoundment

Freshwater impoundments are often created for waterfowl habitat management and mosquito control by diking. To be effective, the dike system must be continuous and relatively impermeable. Tide gates or weirs across channels may be used as control structures to permit high water overflow and required drawdown. For example, opening a mosquito impoundment to normal water flow after the mosquito breeding period is over is recommended practice in many cases [153].

In addition to the problems created by the dikes themselves, discussed in the previous subsection, impoundments preempt the existing coastal wetlands habitat and convert it to an entirely different type of biological system. The new system obviously favors the purpose for which it is managed.

As an example of benefits, waterfowl and wading birds in marsh areas in Delaware increased tremendously after impoundment. Breeding birds increased in numbers over the unmanaged, natural marsh. Areas of open water with emergent vegetation created by the impoundment were found to be optimum for most ducks and geese. Increased fish populations attracted species of fish-eating birds. One study identified 86 species of birds after impounding as opposed to 55 species in the same areas before impounding [145].

Single purpose wildlife and fishery management programs of the past that seek to improve habitats for preferred species are more carefully reviewed today. The feasibility of such a program includes balancing the loss of natural values of the salt marsh or swamp against sustaining or creating management impoundments. As recognized by Delaware's State Planning Office when discussing impoundments: "All marshes should not be converted into impoundments, but on the other hand, the presence of some impoundments may enhance the coastal area and man's enjoyment of it" [145].

4.18 OFFSHORE AND PLATFORM STRUCTURES - SUBPROJECT 18

This subproject addresses the subject of offshore structures, principally platforms used in drilling and oil and gas production. It does not include the transport of oil and gas from the platform to the land (these aspects are discussed in Subprojects 19 and 20). The subject matter includes installation of the structures and their drilling and production operations.

4.18.1 Summary

Offshore drilling and production platforms built and used in the United States are large structures made of steel framework welded to tubular steel legs. This framework is called the jacket, and the working surface that rests upon it is the deck. The two are built separately and joined together on location after the jacket itself has been placed on site. The jacket stands on pilings driven through its tubular steel legs into the floor of the sea.

Drilling derricks are erected upon the platform deck, and up to several dozen production wells may be drilled through the base of a platform. When ready, the deck facilities are changed from drilling to production equipment, and pumping is started. Pipelines are the usual method of transport for oil and gas, but the oil can be shipped by vessel.

In the Gulf of Mexico the trend has been to construct a master production platform and install crew quarters, separators, compressors, and other components on satellite platforms which are connected by footbridges to the production platform.

4.18.2 Activities

The location, design, placement, and operation of offshore platforms is a partnership effort between the oil company and its specialized subcontractors and construction is regulated by USGS. However, the major decisions that affect marine ecosystems--location and operation of platforms--are made almost exclusively by the company and approved by USGS. Major disturbances that arise from inappropriate placement and inadequate operational safeguards are benthic disruption and spills caused by accidents related to the well casings and blowout prevention valves. Other lesser impacts are caused by pollution from drill cuttings and mud and leakage from abandoned wells. On the other hand, platforms often attract an abundance of fish and become popular fishing spots.

Placement of Structures: While actual installation of a platform is a minor concern, its location may be the key determinant of its permanent ecological effects or benefits. If properly placed, the platform will avoid any vital areas, such as shellfish beds, spawning grounds, rich feeding areas of commercial fishes, and critical flyways of migratory birds. Structures should also avoid productive fishing grounds and navigational routes. Any vital areas outside the lease area but wihtin the trajectory of a significant spill from the platform should be known so that sites in areas of special biological significance can be avoided.

There are three requirements for information that precede the approval of a platform site. First, all ecologically vital and other critical areas (fishing, anchoring, ship lanes) in the lease area must be identified and described. Second, the probable trajectories of oil spilled at proposed platform sites should be appropriately computed. Third, all ecologically vital and other critical areas within range of a significant spill must be identified and described.

Drilling: The complex ecological requirements for OCS drilling operations are the subject of much interaction between the FWS and other agencies and are so site-specific that generalization is quite difficult. The subject is discussed briefly below.

The major concern is well blowouts (from subsurface pressures) which can cause substantial releases of hydrocarbons into the water. It has been reported that on the average one blowout occurs for every 2,860 offshore wells drilled [2]. The famous Santa Barbara spill occurred from subsurface escape of oil through a weak geological structure which fissured at the ocean floor. Much more common are blowouts that come up through the well casing and are not stopped by a blowout preventer. In drilling, this may start because the drilling mud is not heavy enough to hold down the pressure, but ultimately the cause is a defective, inactive, or missing blowout preventer. Effective blowout preventers, as well as "downhole control devices", also function during topside accidents or emergencies to prevent large amounts of oil from escaping. It has been noted that "when hurricanes have passed through offshore oil and gas fields, entire platforms have been swept away with only minimal spillage" [107]. Constant surveillance may be required to assure that the well operators keep the preventers in place and in good order. Because accidents happen even then, it is advisable to avoid drilling at sites that would significantly imperil nearby ecologically vital or other critical areas.

The disposal of drill cuttings and drilling mud during drilling is a matter of some concern. If the platform site is not in a vital area, these problems are greatly simplified. The drill cuttings tend to pile up under the platform and to dissipate very slowly. Where they do accumulate, they temporarily eliminate bottom life. The mud may cause local turbidity and contamination from any heavy metals they may contain. Federal OCS orders (issued by USGS) normally require that any drilling muds or drill cuttings containing significant amounts of free hydrocarbons not be disposed of in the sea. Biocides used during drilling may also affect nearby aquatic resources.

Production Operations: The major problems in the production period, other than oil spills, are disposal of "formation water", which may be briny and sulfurous wastes that are separated from the oil stream on the platform in a process called "free water knockout" (gravity separation). Emulsions of water remaining in the oil stream are removed by heat or chemical treatment.

Producing wells require safety measures to lower the risk of blowouts and accidental spills. In wells "capable of flowing oil and gas", storm chokes, or down-hole surface-actuated safety devices, are required to prevent accidental leaks from a well that goes out of control [165]. Still, there is the chance that mechanical defect or operator negligence can cause failure.

Abandonment: The principal ecological concern involving abandonment of wells (including exploratory wells) is that they be properly plugged to avoid any leakage of hydrocarbons or other toxic substances into the sea. This plugging (15 feet below the surface) is required by USGS regulations.

The removal of an existing platform will eliminate the "artificial reef fish concentration area" created during its existence on site. Much public opposition may be encountered as rigs are abandoned and moved. The responsibility of leaving a structure and its maintenance after well abandonment are unresolved legal questions.

4.19 MARINE TRANSPORTATION SYSTEMS - SUBPROJECT 19

Marine shipment of oil and gas is a subject of environmental controversy because of possible oil spills, bilge cleaning activities, and release of highly flammable liquefied natural gas (LNG). Oil and gas may escape into the environment at many points from wellhead to destination on land. In the transportation system, small-volume spillage occurs routinely, particularly at transfer points. Accidents, human errors, and equipment failures can cause large spills at any time [22]. Advanced design, construction and operation of ships and terminals can reduce the potential for disturbance.

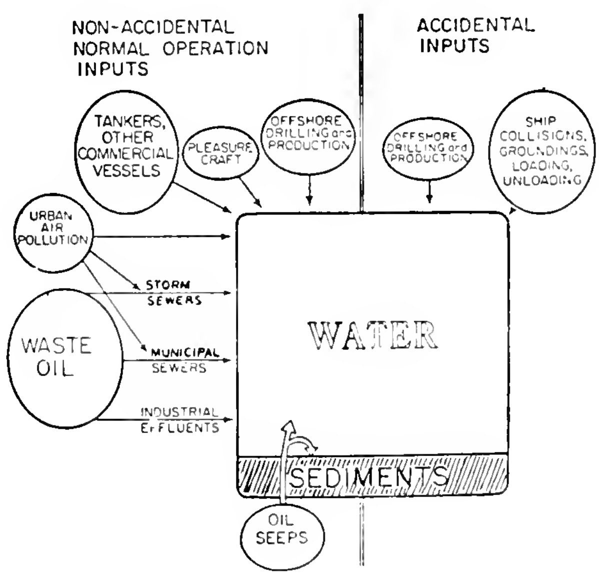
4.19.1 Summary

Marine transportation systems include all modes of surface transport of oil and gas, principally oil tankers, oil barges and LNG carriers. Submarine pipelines for oil and gas transport are covered in Subproject 20. These transport systems provide the links between many diverse oil-related facilities, including offshore platforms, refineries, onshore terminals and LNG regasification plants.

Equipment for transferring oil and gas between a facility and a ship is also a part of marine transportation systems. Flexible hoses, fixed couplings, pumps and metering devices are the principal system components.

The major disturbances caused by marine transportation of oil and gas are: (1) oil spills, (2) routine discharges of oily ballast and bilge waters and tank cleaning water, and (3) LNG releases. LNG releases are of the most direct human concern because of the danger of a disastrous fire in a heavily inhabited area. Oil spills are less directly hazardous to humans but have serious short- and long-term effects on fish and wildlife. Discharges of polluted bilge water add to the potential for adverse effects. Figure 49 illustrates some pathways of oil input to the oceans.

Figure 49. Pathways of oil input to ocean waters (Source: Reference 166).



The U.S. Coast Guard monitors all oil carriers within United States waters to assure that they comply with Federal regulations. They must have and maintain modern navigational equipment. No discharges of bilge wastes, ballast water, or other polluted water are allowed within 50 miles of shore. Enforcement of these and other standards have been only partially successful [167]. The Coast Guard and other Federal agencies have developed regional plans for cleanup following oil spills.

Most oil spilled into water initially floats at the surface. However, wind and water forces effectively distribute spilled petroleum hydrocarbons into all components of the marine and coastal environment, including the water column, sediments, and the atmosphere.

4.19.2 Oil Tankers

World tanker tonnage has increased four fold in 12 years. At the beginning of 1976, Commerce Department figures show there were 5,311 tankers in the world, with a total bulk of 302.3 million tons [168].

Tankers vary in size from 10,000 tons to 500,000 tons (see Table 29). Smaller vessels are used to make short runs in congested

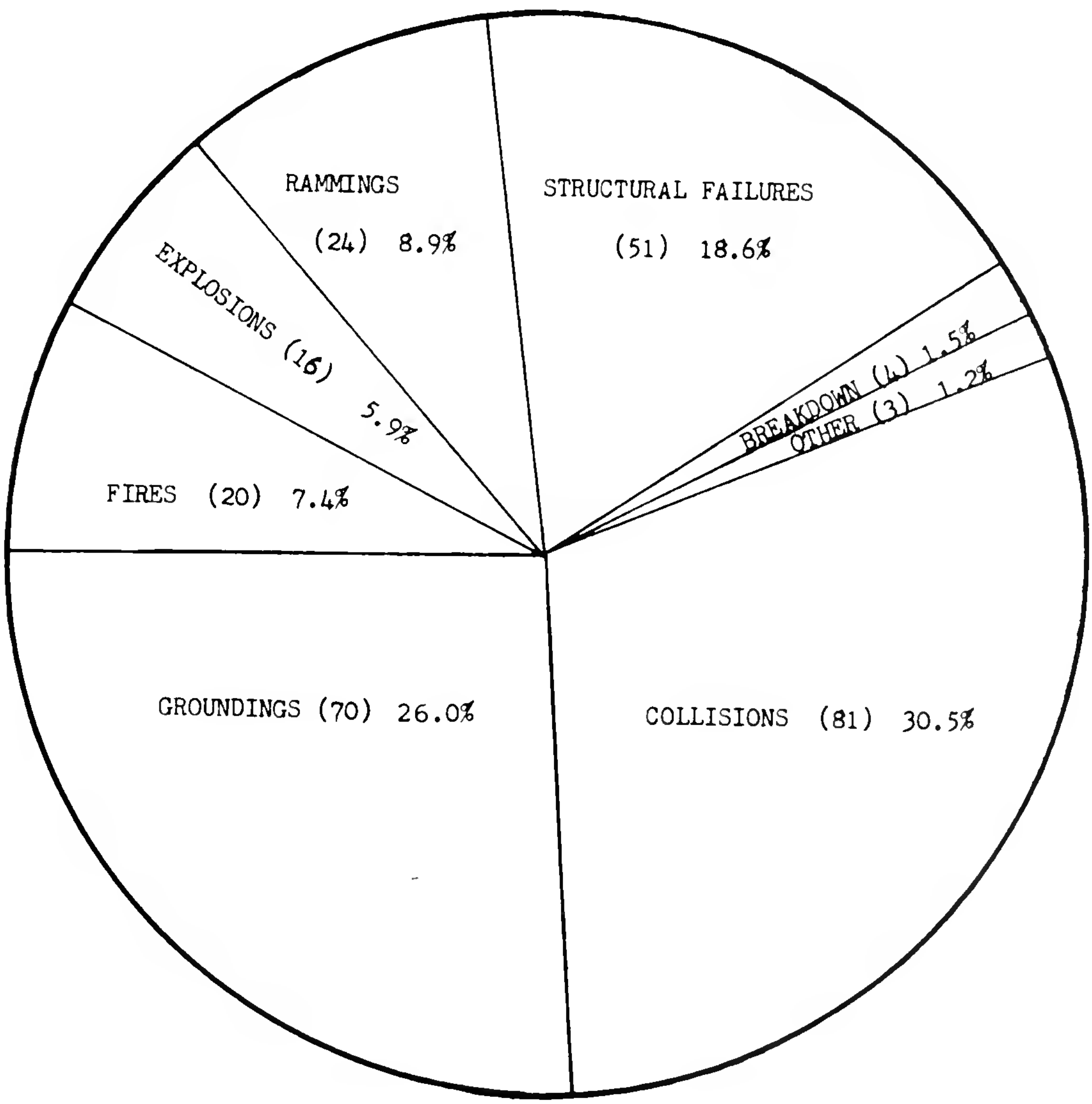
Table 29. Tanker Dimensions and Pumping Rates (Source: Reference 8)

Tanker Sizes (X 1000)		Dimensions (Ft.)			Max. Tons Water per hour	Pumping Rates Barrels Oil per Hour
DWT	Barrels	Length	Beam	Loaded Draft		
20	140	580	72	32	2,000	14,000
40	280	715	93	37	4,000	28,000
50	350	740	105	39	4,000	28,000
70	490	800	117	41	6,000	42,000
100	700	850	128	49	8,000	56,000
150	1,050	980	149	54	10,000	70,000
250	1,750	1,125	170	65	13,000	91,000

coastal areas. Most new ships are giant supertankers (e.g. 200,000 tons or more) which are more economical on long trips. However, the larger ships have too deep a draft to navigate in most American harbors and must be moored offshore, necessitating additional transfer to pipeline or small tankers to move the oil ashore.

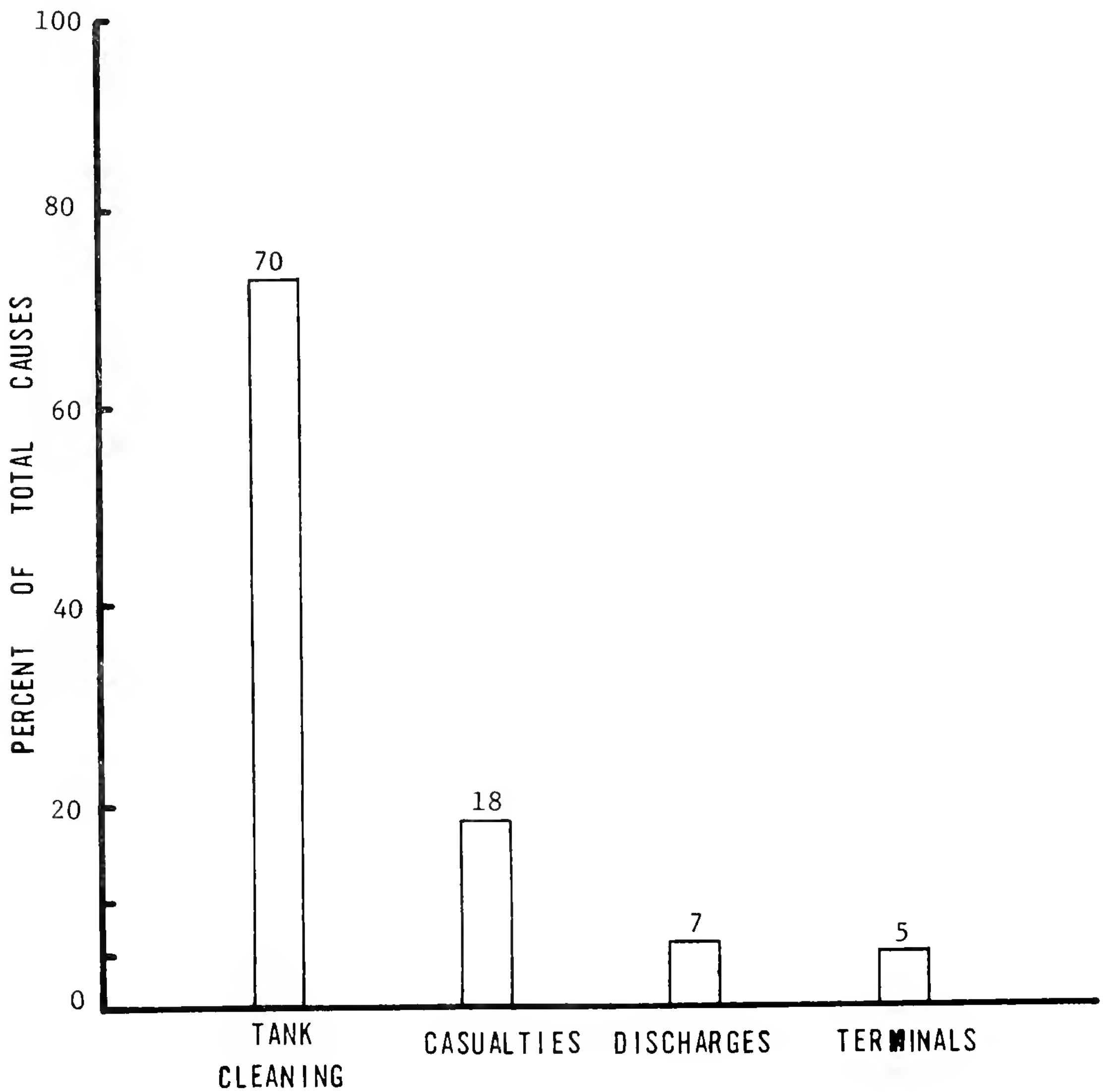
Pollution effects from tanker spills are related in size and frequency to a number of variables. Vessel age, design, degree of compartmentalization (number of oil storage tanks in a ship), and prevailing weather conditions are directly related to the frequency and magnitude of oil spills. Other factors are the regulations governing operations in severe weather, the size of the tanker, and the nation of tanker registry. Human factors include the degree of a crew's operational experience in particular waters and harbors, the degree and quality of their training, and the nature of their operations. The types of accidents that release oil and the percent of the total volume of spilled oil that was caused by each type are shown in Figure 50.

Figure 50. Type, number (in parentheses) and percentage of the polluting incidents resulting from tanker accidents (Source: Reference 169).



Intentional discharges of oily ballast and bilge water is such a common practice that it is a greater source of oil pollution than oil spills. Approximately 70 percent of all oil released from tankers is due to these routine discharges [170]. (See Figure 51.) After delivering oil, tankers

Figure 51. Relative magnitude of oil influx from various tanker sources (Source: Reference 169).



must take on ballast water for the return leg of their voyage in order to maintain seaworthiness. Oil clinging to storage tank walls is washed off by the seawater used as ballast. When the tanker arrives to obtain another load, it discharges the oily ballast water. If the cargo is different in composition than the oil previously carried, the tanks are washed out with hot seawater, which is also dumped. The amount of oil released to the sea in tank washings, ballast, and bilge waters is estimated to be about 0.4 percent of the cargo carried [7]. Thus, a 100,000 ton tanker carrying a full load of 700,000 barrels would discharge 2,800 barrels of oil each round trip, or 135,000 gallons. In comparison, 1,000 gallons of oil is considered to be a major spill [107]. Table 30 summarizes the causes of oil pollution by tankers and other vessels, in comparison with non-marine operations.

Oil spills from tankers due to bilge pumping, leaks, and bunkering operations occur as follows:

1. Bilge pumping - The bilge is the lowest point of the ship's inner bottom and is used to collect oily wastewater from the machinery spaces. This wastewater is discharged at regular intervals.

2. Leaks - Leaks occur due to cracks in the hull. Welded construction and double bottoms reduce leaks to a negligible quantity.

3. Bunkering operations - Discharges during refueling operations are similar to those that occur during cargo transfer and have similar causes.

Several improved design features and operational procedures can be implemented to reduce oil pollution. Some are required in various State and Federal regulations. Those that are optional are used by industry if seen to be cost effective. Most U.S. ships are now constructed with double bottoms for additional safety in case of grounding. A double bottom uses an outer wall for the hull of the tanker and an inner wall for the structure of the oil tanks. The space in between can be used for ballast.

About 80 percent of tankers now use the Load On Top (LOT) procedure that essentially allows for gravity separation of oil and ballast water during the noncargo leg and the discharge of the bottom stratum of denser seawater before entering port [171]. In this procedure, a new cargo of oil is taken on and loaded on top of the retained oil. Segregated ballast systems can also reduce oil discharge by providing separate oil and ballast tanks, often designing wing tanks along the side as ballast tanks since they are most likely to rupture from a collision.

Fitting of ships with modern navigational systems could significantly reduce accidents. Added safety could be provided by twin propellers and twin rudders for added maneuverability and operational flexibility and by

Table 30. Estimated Annual Oil Pollution of the Oceans (Source: Reference 169)

Marine Operations 1/	Metric Tons	Percent
Tankers	1,387,000	28.32
1) LOT (Load-on-Top) tank cleaning operations	265,000	5.41
2) Non-LOT tank cleaning operations	702,000	14.34
3) Discharge due to bilge pumping, leaks and bunkering spills	100,000	2.04
4) Vessel casualties	250,000	5.11
5) Terminal operations	70,000	1.43
Tank Barges	70,000	1.43
1) Discharge due to leaks	20,000	0.41
2) Barge casualties	32,000	0.65
3) Terminal operations	18,000	0.38
All Other Vessels	850,000	17.36
1) Discharge due to bilge pumping, leaks and bunkering spills	600,000	12.25
2) Vessel casualties	250,000	5.11
Offshore Operations	100,000	2.04
NON-MARINE OPERATIONS		
Refineries and Petrochemical plants	300,000	6.12
Industrial Machinery	750,000	15.31
Highway Motor Vehicles	1,440,000	29.41
TOTAL	4,897,000	100.00

1/ Marine Operations make about 49% of the total estimated annual Oil Pollution of the Oceans.

auxiliary power systems to propel the vessel if the primary system fails. Holding oily bilge and ballast water and tank washings for discharge to oil/water separation facilities ashore before reloading could obviate the need for many of the above design features.

4.19.3 Transfer Systems

In the transportation system small-volume spillage occurs routinely, particularly at transfer points between different components of the system (e.g., terminal-tanker, refinery-pipeline). Moreover, accidents, human errors, and equipment failures can cause large spills at any time. Spills are difficult to control and can often cause extensive environmental disruption if they reach beaches or marshes. Terminal location and design should be such as to minimize the possibilities of a spill. The less often crude oil is transferred, the less likely it is to spill. For instance, a transfer operation involving pumping from tankers to offshore tanks, to lighters or to refineries, requires three handlings, whereas pumping from tankers to pipelines to refineries involves only two [172].

Oil and gas transfer equipment should constantly be monitored in order to avoid spillage. Flexible hoses on an offshore transfer buoy, or single point mooring (SPM), may deteriorate rapidly when storm waters beat them against or wrap them around an SPM. Fixed couplings may break, particularly when a ship drifts. Pumps may fail and pipelines rupture. LNG transfer equipment is subject to the additional problems of handling a liquid at 260 degrees (F) below zero. This thermal stress can only be overcome by special materials which do not become brittle at low temperatures.

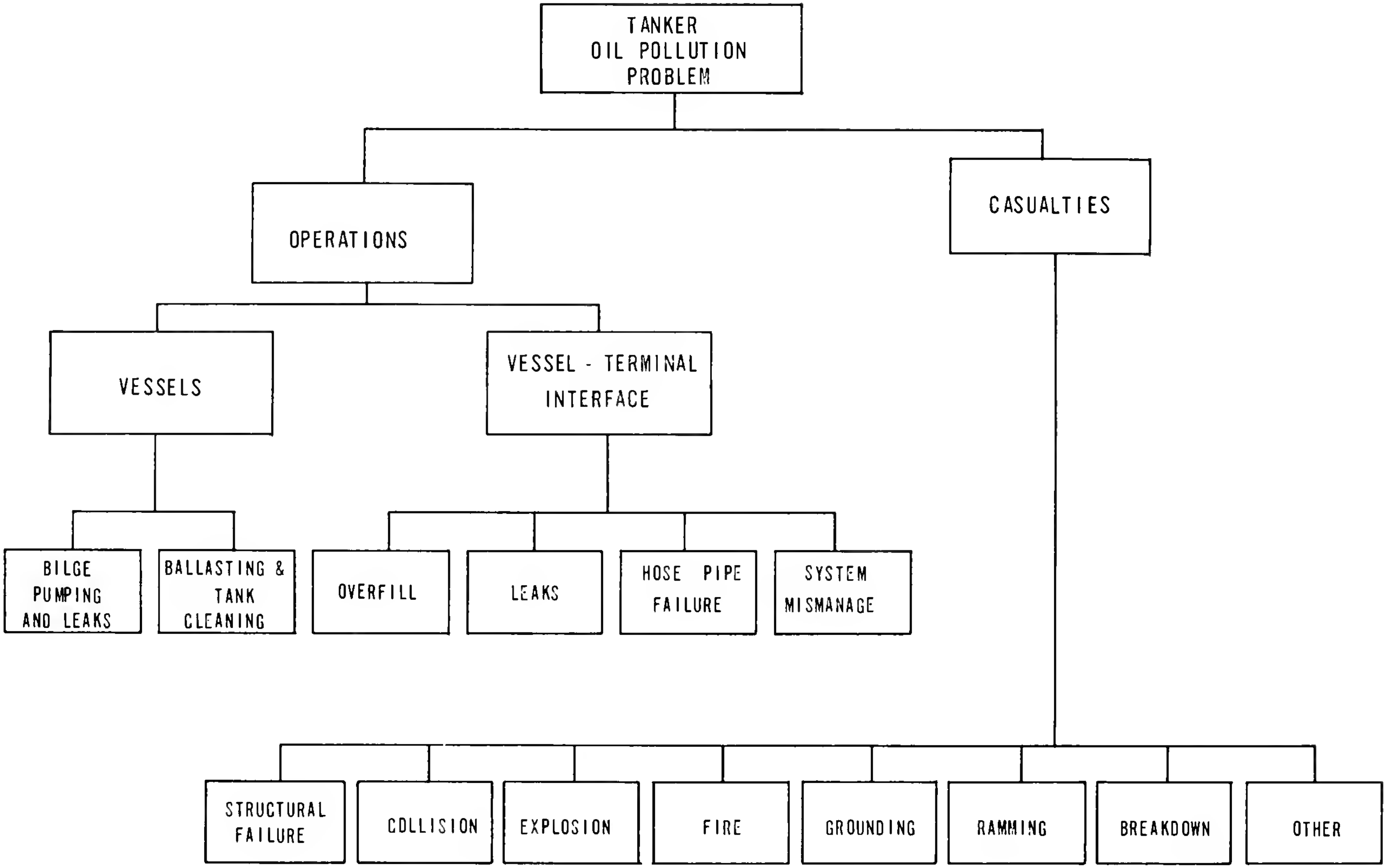
Human errors, such as overfilling and system mismanagement, can be minimized by the use of properly trained personnel in transferring oil and gas, and by systems designed to reduce the potential for error and to monitor human actions.

The breakdown of the ways oil spills can occur as a result of terminal and tanker operations and tanker accidents is shown in Figure 52.

4.19.4 Oil Spill Fate and Containment

Crude oil is a combination of numerous hydrocarbons. Processed oil can include any of the types of oil present in the original crude oil or new petroleum compounds derived from these substances. The types of hydrocarbons spilled will determine, to a large extent, the impact on organisms in the receiving waters. For example, lighter hydrocarbons, such as gasoline and kerosene, will evaporate more quickly than heavier hydrocarbons. Oil with high percentages of aromatic hydrocarbons dissolve in water most easily and are likely to have more serious impacts than oils with lower concentrations of aromatics [7].

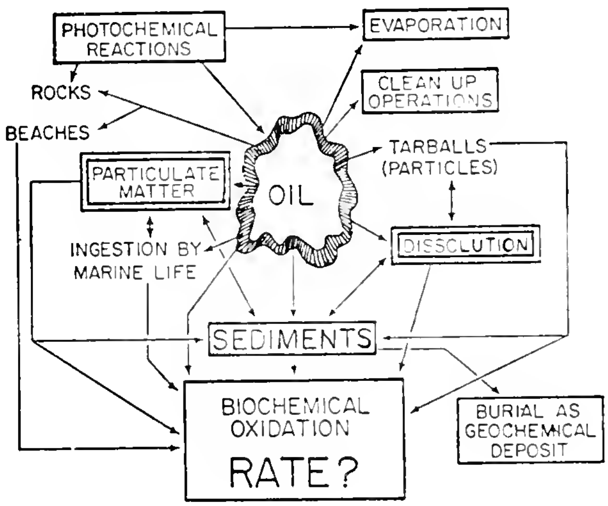
Figure 52. Sources of oil pollution (Source: Reference 169).



When petroleum is spilled into water, hydrocarbons immediately begin to undergo changes at a rate determined by the composition of the petroleum and characteristics of the environment, such as temperature, concentration of bacteria and nutrients, and wind and wave action. These changes occur through evaporation, solution, spreading, emulsification, air-sea interchange, oxidation, biological degradation, uptake, and sedimentation.

Petroleum spilled offshore forms slicks and tar lumps but these are transient conditions. The fate of most spills in the ocean is a combination of evaporation and decomposition in the atmosphere, plus oxidation to carbon dioxide by chemical or biological means. The remaining materials are dispersed in the water column or incorporated into sediments (Figure 53). The more volatile and soluble compounds, representing

Figure 53. The fate of oil introduced into the marine environment (Source: Reference 166).



to

approximately 80 percent of the spill volume, disperse within a few weeks. The heavier fraction of petroleum forms tar lumps which are estimated to have a residence time in the ocean of about a year. Tar stranded on rocky shores may have a much longer lifetime. Oil that becomes incorporated in coastal sands protected from the weathering effects of sun and oxygen may have a residence time measured in years or decades.

Since it is certain that spills will occur from time to time during the operation of a terminal, a plan for containment and recovery operations must be prepared. Success depends on the size of the spill, availability of personnel and equipment, and wind and sea conditions. The closer that a terminal lies to shore, the more rapid must be the response to prevent contamination of coastal systems. In an environmental sense, there is greater risk of shoreline contamination if a port is located within an estuary or near the coast. Special efforts should be made to keep transfer points out of ecologically vital water areas.

The floating boom is currently the primary containment device. It encircles, sweeps, or directs an oil slick to a collection point. Typically, a fence or skirt extending above and below the water surface forms the containment section. Effectiveness of a boom is limited by waves, winds, and currents. Efficiency of the booms drops rapidly when water conditions exceed 6 to 8 foot seas with 20 knot winds and 1.25 knot currents.

Cleanup systems may employ mechanical skimming devices, sorbent straw or foam, and chemical dispersants and sinking agents. Sorbent methods have been most effective, while dispersants and sinking agents may do more damage than good. Efforts to clean up oil with chemical applicants, themselves pollutants, may be detrimental to coastal plants and animals by placing additional stresses on the ecosystem. Cleanup systems have collected surface liquids in 8 foot seas that were more than 70 percent oil.

To date, oil spill containment and cleanup systems or equipment are far from 100 percent effective in controlling and removing pollution under most weather and sea conditions. None is effective in turbulent seas where wave heights exceed 8 feet [5].

4.19.5 Ecological Disturbance

Petroleum spilled along the coast is potentially toxic to virtually all marine and coastal organisms including waterfowl, mammals, fishes, shellfishes, reptiles, and plankton. Nearshore and estuarine areas are vulnerable to offshore oil spills because of shoreward winds, currents, and tides.

Aromatic fractions (many of them water soluble) are the most toxic to many marine organisms. Concentrations of water soluble aromatic derivatives as low as 0.1 part per million may be toxic to larvae. Adult organisms are sensitive to concentrations of 1 part per million. Crustaceans and burrowing animals are most sensitive, fishes and bivalves moderately sensitive, and gastropods and plants are least sensitive [173].

In addition to lethal effects, the major adverse environmental effects of direct oil pollution of coastal waters are: (1) sub-lethal effects including disruption of the physiological, behavioral, and reproductive activities of aquatic species; (2) changes in physical and chemical habitats, causing exclusion of species and reduction of populations; and (3) incorporation of hydrocarbons into the food chain and other stresses on the ecosystem resulting in altered productivity, system metabolism and structure, and species diversity. Non-lethal incorporation of hydrocarbons in organisms is of interest because of potential accumulation of aromatic hydrocarbons, especially carcinogens, in various marine organisms, and because of tainting (developing an objectionable taste) of edible organisms with hydrocarbons.

The biological effects of oil spills are determined by the following factors [5]:

- Type of oil spilled, in particular, the concentration of lower-boiling aromatic hydrocarbons
- Amount of oil
- Physiography of the spill area
- Weather conditions at the time
- Biota in the area
- Season of the year
- Previous exposure of the area to oil
- Exposure to other pollutants
- Method of treatment of the spill.

Oil on Shore: When an oil slick reaches the shore, its behavior depends on the nature of the oil, its emulsions, and the shore. Usually, much of the oil will be carried to the beach along the high-water mark by successive tides. Well-weathered or heavy oils mixed with sand or plant debris during this process form oil-cakes that sink into sand and gravel or cling to seaweeds.

Pebble beaches are troublesome to clean, because the oil may sink among the pebbles to a depth of several inches. Oil does not sink so readily into wet sand. Breakers may, however, throw fresh sand over the oil-containing sand, burying it. In this way a beach may appear clean shortly after an oil slick has come ashore. Later removal of surface layers during storms or in seasonal sand-movements exposes the oil.

Oil may also persist on dry rock surfaces or among weeds, barnacles and mussels, where it slowly erodes or flakes off because of drying and hardening, or because it incorporates with sand particles. Oils cling to the byssus-threads of mussels and to the outer layer of shells and certain upper-shore weeds, which have a naturally oil surface. Oil also contaminates some marine grasses and flowering plants.

Toxic Effects: Sensitivities of phytoplankton to petroleum vary over a wide range. Kelp and other large marine plants are apparently reasonably resistant perhaps due to coatings of mucous substances on the stems and fronds of the plant. Long-term impacts of spilled oils on plants depend on both toxic and coating effects, frequency of coating and on the time of year [173].

Toxic effects of oil on larval stages of many marine organisms show that larvae are 10 to 100 times more sensitive to oil than adults. Typically, larvae may develop abnormally, leading to death several weeks after exposure. Such malformed individuals are usually more susceptible to predation, and unsuccessful in competition for food. Larvae tend to be more sensitive than eggs [173].

Bivalves, including oysters, clams, cockles and mussels are moderately oil resistant. The ability to close and seal their shells apparently provides protection. However, this closed condition cannot be maintained indefinitely. In fact, cockles tend to "gape" making them more susceptible. Light crude oils and some petroleum products may be able to penetrate the minute shell openings through which mussels secrete the byssus threads that attach them to rocks [173].

Coating: Organisms most endangered by coating are those unable to leave the area where weathered oil is emulsified, dispersed in the water column, settled to the bottom, or coats the shore. This immediately excludes most finishes and other mobile pelagic organisms, which can detect low concentrations of oil in seawater and usually avoid higher concentrations. However, some fish larvae (such as herrings) may not be able to avoid oil and lobsters are known to be attracted. Birds and marine mammals present different problems since they may not recognize an oil slick until coating is inevitable or has already occurred [174]. Whether or not an organism can move away from oil deposited on the ocean bottom plays a large role in determining whether or not it survives the exposure.

In many filter-feeding organisms (such as clams, snails, barnacles, and shrimps) the feeding and respiratory organs are closely coupled. Therefore, interference with one almost inevitably affects the other. Many shellfishes filter water through their gills and strain out everything. Indigestible material is formed with mucous and ejected. As long as the amount of oil is small, the organisms is usually able to surround the oil with mucous and eject it. A heavier emulsion will probably suffocate the organism [174]. Subtidal benthic species are somewhat protected from coating because oil does not occur as a film on subtidal substrates except in the worst local spill situations [5].

Warm-blooded marine organisms must maintain their body temperatures within a narrow range, often at a higher level than the surrounding water. This requires an efficient insulating layer surrounding the body. Whales, seals and walruses use a thick layer of blubber for insulation which is little affected by a coating of oil. Fur seals and sea otters combine fat layers with a thick fur coat as insulation. A coat of oil can significantly change the fur's insulating properties perhaps causing the animal to lose heat and eventually cause death by hypothermia or by lowered resistance to disease. Caged sea otters inadvertently contaminated with oil died within a few hours, apparently from exposure [175].

In Gulf Coast marshes, fur-bearing mammals (muskrat, nutria, otter) get oil in their coats which destroys their insulating qualities and may impede swimming. During cold weather death usually results from over-exposure and in summer overheating may occur. Marsh grasses usually recover in 1 year, especially if the marsh is burned. Animals will return to the marsh when the spilled oil is no longer present [175].

Birds, being warm-blooded, must likewise insulate themselves against heat loss; furthermore, their insulation must be waterproof. Some species of oceanic birds rarely come into contact with oil, whether floating or beached, and thus are not especially endangered. Swimming birds are continually subject to contact with floating oil slicks. Often their first reaction upon coming in contact with oil is to dive beneath it, invariably resurfacing in the slick, compounding the problem. Oil causes the insulating layer of feathers to mat, reducing or destroying their insulating qualities and causing the bird to freeze or die of disease caused by lowered body temperatures. The buoyancy maintained by the air-filled feathers is also disturbed and the bird may drown. Feeding may become difficult, because the bird may have difficulty moving and food sources may also be contaminated by oil. Only limited success has been achieved in cleaning oil from birds and releasing them; high mortalities commonly occur although new techniques and materials are being developed [173] [174].

Persistence: Once mixed in ocean waters, oil is usually absorbed into the surfaces of suspended particles, eventually settling to the bottom. The amount of oil absorbed by sediments is related to particle surface area. In general, the smaller the sediment particles have a larger total surface area. Thus, all other things being equal, there will be more oil associated with clay sediments than with sands [173].

Once incorporated into sediments, oil generally degrades slowly. At the sediment surface, aerobic (oxygen utilizing) bacteria can degrade some fractions of the oil. Deeper in the sediment, there is usually no oxygen and only anaerobic bacteria (which avoid free oxygen) can function. Anaerobic degradation of oil is much slower than in aerobic conditions. Oil in sediments frequently persists for months or years before it breaks down, assuming no new oil is introduced. In the meantime, waves or unusually strong currents can resuspend the oil so that it can be moved into other areas. (Some possible synergistic effects were discussed in a previous section.)

Sediment particle sizes also play a major role in determining which organisms live in the sediments. Detritus feeders such as many gastropods and bivalves, tend to live in fine sediments (silt and clay). These animals ingest sediment particles, digest bacteria and organic matter, and excrete the remainder in fecal pellets. Filter feeders inhabit coarses sediments (sand and gravel) and filter their food from the water. For both detritus and filter feeders, oil in the sediments and water column presents other dangers, such as the absorption of hydrocarbons through the digestive tract and the destruction of food sources [173].

4.19.6 Liquefied Natural Gas (LNG) Carriers

LNG carriers are in limited use in the United States, and have minimal potential for ecological disturbance. Accidents involving LNG carriers are of great concern, although few major incidents have occurred. In the event of an escape of LNG, there is very rapid formation of a vapor plume, which its low temperature causes to hang close to the water areas until its temperature increases to make the gas lighter than the air. Unconfined, the vapor mixed with air is not explosive, but in a mixture of 5 to 15 percent vapor and air it is highly flammable. Within enclosed spaces, if mixed with air in the presence of an ignition source, it can explode. The primary danger present in a large-scale LNG spill is a very intense fire at the spill site. A more remote hazard is that the vapor plume could drift into enclosed spaces adjacent to a spill site and explode or catch fire [176].

For these reasons, all LNG facilities should be sited as far as possible from inhabited areas. Furthermore, strict safeguards should be applied to any such development, such as elimination of ignition sources, and maintaining buffer zones around LNG tanks.

4.20 SUBMERGED TRANSMISSION SYSTEMS - SUBPROJECT 20

This discussion of transmission systems is limited to submerged oil and gas pipelines. These pipelines transport 98 percent of the oil produced on the United States OCS. While they have a lower potential for major oil spills than tanker transport, stringent safeguards are in order. Proper design, location, construction, and operation of pipelines will minimize the risk of oil spills and the disruption of benthic communities and offshore vital areas.

4.20.1 Summary

Submerged transmission of oil and gas is conventionally done by marine pipelines. These serve as oil transport linkages between offshore platforms, subsea wells or single-point mooring (SPM) systems and onshore facilities. Generally, pipelines represent the most efficient, economical and cleanest method of moving bulk liquids. Given suitable volume, terrain, and design life, they are the optimal transfer system [9].

Pipeline construction is costly and complex. Forty foot sections of steel pipe are coated ashore and transported to the OCS site. The coated sections (generally greater than 12-inch diameter) are welded together on a "lay barge" and allowed to sink under their own weight to the sea floor. In water depths less than 200 feet, the pipeline is buried by water jet excavation as required by USGS. As the pipeline comes ashore, it is buried deeply enough to avoid being exposed to storms. Due to these difficult construction stages, costs for a long, deep pipeline may exceed $1 million per mile [7]. Oil production of about 1,000 B/D <u>per mile</u> of pipeline is needed to justify such a large capital investment.

The decision to build oil or gas pipelines is made when a hydrocarbon reservoir is developed. If there is sufficient gas, a pipeline will be built because gas cannot be shipped by barge. If there is not enough gas it is reinjected or capped for possible later pipelines. Large volumes of oil are also generally piped if the water is not too deep. The oil and gas can be piped together for short distances, but there are technical difficulties involved in pumping an incompressible fluid and a compressible gas in the same pipeline [7]. Thus, oil and gas are usually separated on the offshore platform before delivery to the pipelines. Partial processing at the platform to remove formation water has two additional savings. There is a smaller volume of fluids to pump ashore and there is less corrosion inside the pipeline.

Submerged bottoms or coastal wetlands and their associated organisms, may be seriously affected by pipeline installation. In addition, dredging produces spoil, which must be disposed of (see Section 4.1 for problems of spoil disposal). Disposal of spoil can destroy habitat that may extend beyond the area of primary concern.

The U.S. Geological Survey regulates submerged pipelines from oil and gas fields. Information that the operator is required to provide the Survey includes: proposed route, water depths, capacity, operating pressures, size and grade of pipe, burial depth, corrosion protection, protective coating, connecting and metering facilities, and pressure control facilities. The methods of welding and laying, installation, and connecting facilities are monitored and a hydrostatic test is made upon completion of installation [2].

4.20.2 Location

The general location of a pipeline landfall site is primarily determined by the shortest possible route between the production platform and land. Once the general location for landing a pipeline has been selected, the choice of landfall site will depend upon the physical characteristics of the shore and the company's production plans [7].

Major potential disturbances to fish and wildlife stem from construction of the pipeline in vital areas, and from oil leaks and spills from pipelines during operation. Locating a pipeline in a vital area, such as a coral reef, shellfish bed, or fish spawning area, will have an adverse impact. In addition to preempting or disturbing prime habitat, large volumes of sediment may be suspended during pipe burial. Oil spills from rupture of the pipeline or leakage from joints and connections may cause disturbances from direct hydrocarbon pollution or pipelines may emit a continual trickle of oil, which can result in long-term accumulation in sediments.

While recognizing that longer pipelines consume more raw materials, all efforts should be made to detour around geologically hazardous or environmentally vital areas. The initial avoidance of vital areas while siting a pipeline corridor may avert many short and long-term disturbances to fish and wildlife. The avoidance of areas subject to geologic hazards, such as mudslides, sediment liquefaction, or earthquakes, will result in a lower risk of oil spills and their environmental consequences and expense to oil companies.

4.20.3 Design

The design of a pipeline system depends on factors such as the characteristics of the oil or gas well stream (its pressure, temperature, and specific gravity) and the distance between the producing field and shore. Variables include the production rate, whether separation takes place on the platform or onshore, and desired operating pressures for the pipeline. These factors and variables influence the pipe diameter, pipe thickness, and number of intermediate pressure booster stations required, if any [7].

The design of a submerged oil or gas pipeline is a complex engineering problem. A design is sought which will meet all operational necessities and safety requirements and still be environmentally acceptable. Pipe selection is an important consideration. The proper pipe diameter must be chosen first (usually from 14 to 44 inches) and then to the pipeline and its expected contents must be designed to be stable. If the pipeline is too light, it will gradually work its way up through the soil and become exposed to the water forces. If it is too heavy, it may gradually sink into the bottom and impose additional stress in the line. Design procedures for determining the vertical stability of the line in sands and clays are available [107]. The pipe wall and coatings must withstand the bending stresses encountered during pipe laying. The coatings and pipe must be designed to resist corrosion for the expected lifetime of the pipeline, usually 20 years.

Of the various design procedures that can make a pipeline more environmentally sound, first and foremost is that the pipeline must be engineered to be safe. This implies that the design life of the pipe should exceed the period during which it will be used. Second, the largest of feasible alternative pipeline diameters should be chosen.

This would allow an existing pipeline to accommodate flow from a future nearby find and thus limit additional pipeline laying. Although more materials would be required to build a larger pipeline, less energy would be expended in pumping oil or gas.

An important design requirement is to incorporate suitable leak detection sensors and line shut-off valves at key points in the pipeline system.

4.20.4 Construction

Laying a marine pipeline is a major activity that has the potential for environmental disturbance. A "lay barge spread", the unit which lays the pipeline, consists of a lay barge, one to three tug boats, and pipe supply vessels. In shallow situations where burial of the pipeline may be required (less than 200 foot depth) a "bury barge", or "jet barge", is added to the flotilla to do the work. Burial is effected by jetting sediment from underneath the pipeline. As the jetting device ("jet sled") is pulled forward along the bottom the pipeline settles into the trench and is partially buried by the sediments as they settle back into the depression. Complete burial can then be accomplished by either using a drag sled which pushes sediment back into the trench or by additional jetting from the side [107].

In all shipping fairways and anchorage areas, pipelines must be buried at least 10 feet deep regardless of water depth. Only lines in the gathering system between adjacent platforms may remain unburied in the shallower areas. In some areas, such as the Southern California OCS, the water depth requirement has been increased to 250 feet. In addition, offshore pipelines are required to be coated for mechanical and corrosion protection. Electrolytic protection against corrosion is also required [139].

The use of high pressure water jets to bury pipe increases turbidity which may affect benthic organisms. Disruption of sediments will have greater adverse effects in populated and industrialized harbors where sediments may be polluted. In shallow waters, experience has shown that bottom restoration is rapid, whereas in deeper waters, more than a year may be required. The selection of pipeline routes along bedrock requires the use of underwater blasting which may kill marine animals in the blasting area [7].

The principal safeguard required over the whole pipeline run is avoidance of vital areas (reefs, spawning areas, kelp beds, etc.) by suitable alignment of the pipeline. Specific construction mitigation measures are required in shallow areas, particularly in estuaries. These include the use of special construction techniques, such as use of sediment screens and other siltation prevention techniques during underwater trenching,and scheduling jet-sled operations to avoid critically sensitive periods, such as breeding and rearing.

4.20.5 Operations

According to many studies, onshore pipelines are considered the safest means for bulk transport of hydrocarbons. In spite of the severe marine environment, offshore pipelines are reported to be less prone to oil spills than onshore pipelines.

The largest spills occurred prior to 1970 and when pipeline ruptures often were caused by dragging anchors. The largest pipeline spill occurred in October 1967 when a vessell dragging its anchor in a storm severed a pipeline about 20 miles west of the mouth of Southwest Pass, Mississippi River delta, Louisiana. The resulting spill went undetected for 10 days and released over 160,000 BBL of oil into the Gulf of Mexico. Since 1970, spillage from pipelines has been considerably reduced as a result of several precautions in location, design, and construction of pipelines.

Although some of the largest pipeline spills have been accidents, such as breaks from anchor dragging, most pipeline spills result from failure of older pipelines [139]. Corrosion by the forces of seawater and shifting bottom sediments, from without, and by hydrogen sulfide, dissolved oxygen, saltwater and fatty acids, from within the pipe, lead to pipeline failure. Failures due to external corrosion (80 percent) exceed those due to internal corrosion (20 percent) [5].

Safe operation of a pipeline system requires continuous line pressure monitoring systems with automatic shut down valves or alarms, and regular pipeline inspection for leaks [139]. The primary leak detection system in use (required on all lines built after March 13, 1970) is a set of automatic pressure sensing recorders on both ends of each pipeline system. These devices are equipped to either shut down the flow automatically or to sound alarms in event of an abnormal pressure level. The system is sensitive only to leaks which cause a decrease in line pressure greater than 300 to 500 psi and therefore is essentially a safeguard against the effects of a catastrophis line break [107].

The second system of leak detection, useful mainly in intertidal areas (and onshore), is routine patrolling of pipeline route by boat, aircraft, or wheeled vehicle. Inspection at intervals not exceeding 2 weeks is required. This type of monitoring would be of little consequence in preventing losses of a large amount of petroleum in the event of a major break. Regular pipeline patrolling allows detection of small leaks, and therefore, complements the pressure-sensing system described above [107].

A third system for detection consists of reading and comparing the volume-recording flow meters on either end of a pipeline system. Because crude oil moves from OCS areas to shore by common carrier lines, meters are required at the offshore pipeline gathering system and again at the onshore pipeline terminal in order that each producer be properly credited for his share of the common stream. The flow sensors continually measure input and output allowing attendant personnel who record these readings for inventory control to discover a decrease in output which would indicate a leak [107].

A fourth safety feature which can be built into all pipelines is the incorporation of automatic shut off valves at the wellhead, landfall, and near certain ecologically vital areas [107]. These may be self-activating upon a sudden drop in pressure, but it may be more practical to have them electronically controlled from the land or the offshore platform.

4.20.6 Shore Zone Installation

At the landfall, pipeline installation has its highest potential for adverse effects. Special safeguards are necessary to protect dunes, barrier islands, marshes, and estuaries. The battering of pipe by sand-laden surf hastens corrosion and leakage, so the pipe must be deeply buried beyond the anticipated shore recession profile. Deep trenches in shifting beach sands are hard to excavate and require a major movement of sand. This may alter the shoreline configuration. Lateral transport of sediment, affecting beach erosion and nourishment, may be affected by the placement of submarine pipelines.

Pipeline installation in wetlands can cause significant disruption because the canals used in pipe-laying operations convey saltwater inland. The intrusion of saltwater upstream in canals often has serious adverse effects on inland systems, rendering the water unsuitable for fresh or brackish fish and wildlife species, killing freshwater marsh and upland vegetation,and in some areas causing salt burns in soil where no vegetation will grow. Seawater encroachment contaminates human and agricultural water supplies, necessitating costly treatment or relocation of intake points. Increased salinity in the upstream environment also results in increased corrosion and shorter life expectancy for engineering structures. The construction of barriers (sills or weirs) across drainage canals near their point of entry to the estuary to prevent saltwater inflow provides only a partial solution because a sill must also be low enough to provide drainage of upland areas during rainfall.

There has been sufficient experience with landfalls to cite some specifics. Experience shows that the shore approach should be gently sloping with sufficient depth of sand or gravel to give not less than 10 feet of cover over the pipeline down to the low water mark and 7 feet of cover out to a depth of 50 feet. Areas subject to seabed shifting or strong tidal flows should be avoided. Erosion caused by such action could undermine pipeline support, placing additional stress on the pipeline and possibly causing it to fail. While the landfall site should allow for a flat approach or reasonably gentle transition from marine to land environment if possible, cliffs up to 100 feet can be accommodated if the rock is soft.

Significant ecological problems have occurred in shore regions of Louisiana where pipeline dredging has resulted in canals connecting bodies of water which would otherwise be separate (see Section 4.7). The resulting environmental changes have generally been adverse. Present practice is to dam these canals in order to prevent this intrusion.

REFERENCES

1. Ellis, R.H. 1972. Coastal Zone Management System: A Combination of Tools. Marine Technological Society. Washington, D.C.

2. U.S. Department of Interior, Bureau of Land Management. 1977. Draft Environmental Impact Statement, Proposed Outer Continental Shelf Oil and Gas Lease Sale Western Gulf of Alaska - Kodiak. Bureau of Land Management. Washington, D.C.

3. U.S. Department of Interior, U.S. Geological Survey. N.D. OCS Orders Governing Oil and Gas Lease Operations in the Outer Continental Shelf, Mid-Atlantic. U.S. Geological Survey Conservation Division. Washington, D.C.

4. U.S. Department of Transportation, U.S. Coast Guard. Office of Marine Environment and Systems. 1975. Final Environmental Impact Statement, Deepwater Port Regulations. U.S. Coast Guard, Office of Marine Environment and Systems. Washington, D.C.

5. Council on Environmental Quality. 1974. OCS Oil and Gas - An Environmental Assessment. U.S. Government Printing Office. Washington, D.C.

6. Stewart, R.J., J.W. Devanney III, and W. Briggs. 1974. Oil Spill Trajectory Studies for Atlantic Coast and Gulf of Alaska. In Primary, Physical Impacts of Offshore Petroleum Developments. Report No. MITSG 74-20. Cambridge, Massachusetts.

7. Ciampa, V.F., et al. 1976. Onshore Facilities Related to Offshore Oil and Gas Development Factbook. NERBC/RALI Project, New England River Basins Commission. Boston, Massachusetts.

8. Arthur D. Little, Inc. 1975. Petroleum Development in New England: Economic and Environmental Considerations, Volume II, Modular Results. Energy Program Technical Report 75-6. New England Regional Commission. Boston, Massachusetts.

9. Oceanographic Institute of Washington. 1974. Offshore Petroleum Transfer Systems for the State of Washington: A Feasibility Study. A Report to the 44th Legislature, State of Washington, by the Oceanographic Commission of Washington. Seattle, Washington.

10. Halper, M. 1974. Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Petroleum Refining Point Source Category. Environmental Protection Agency. Washington, D.C.

11. U.S. Department of Transportation, U.S. Coast Guard. 1972. Polluting Incidents in and Around U.S. Waters. U.S. Coast Guard. Washington, D.C.

12. Pearman, A.L., and J.W. Stafford. 1975. Florida Coastal Policy Study: The Impact of Offshore Oil Development. A Report Submitted to the Florida Energy Office and the State University System of Florida. Tallahassee, Florida.

13. Alaska Consultants, Inc. 1976. Marine Service Bases for Offshore Oil Development. Prepared for the Department of Community and Regional Affairs, State of Alaska. Juneau, Alaska.

14. Urban Pathfinders, Inc. 1975. Brown and Root Impact Study. Baltimore, Maryland.

15. Massachusetts Office of State Planning. 1976. Offshore Oil Development: Implications for Massachusetts Communities. Boston, Massachusetts.

16. Arthur D. Little, Inc. 1975. Petroleum Development in New England: Economic and Environmental Considerations, Volume III, Regional Factors. Energy Program Technical Report 75-6. New England Regional Commission. Boston, Massachusetts.

17. Ciampa, V.F., et al. 1976. Onshore Facilities Related to Offshore Oil and Gas Development: Estimates for New England. NERBC/RALI Project, New England River Basins Commission. Boston, Massachusetts.

18. Mutch, D. June 5, 1977. Builders Send Out Two Platforms to North Sea. Offshore. Volume 32, Number 6. Houston, Texas.

19. Robinson, H.T. Brown and Root, Houston, Texas. Personal Communication, June 23, 1977.

20. Public Health Service Division of Air Pollution. 1960. Atmospheric Emissions from Petroleum Refineries; A Guideline for Measurement and Control. Cincinnati, Ohio.

21. Engineering-Science, Inc. 1975. Water Pollution Abatement Technology: Petroleum Refining Industry. Prepared for the National Commission on Water Quality. National Technical Information Service. Springfield, Virginia.

22. LaRoe, E.T., et al. 1975. Coastal Management Aspects of OCS Oil and Gas Developments. National Oceanic and Atmospheric Administration, Office of Coastal Zone Management. Washington, D.C.

23. University of New Hampshire. 1974. Impacts of an Oil Refinery Located in Southern New Hampshire. Durham, New Hampshire.

24. Ciampa, V.F., et al. 1977. Onshore Facilities Related to Offshore Oil and Gas Development; Tech Update 14. NERBC/RALI Project, New England River Basins Commission. Boston, Massachusetts.

25. Steinberg, A., et al. 1973. Potential Onshore Effects of Oil and Gas Production on the Atlantic and Gulf of Alaska Outer Continental Shelf. Appendix IV, Petrochemicals. Prepared for the Council on Environmental Quality, Washington, D.C. by Resource Planning Associates, Inc., Cambridge, Mass., and David M. Dornbusch and Co., San Francisco, California.

26. U.S. Environmental Protection Agency Regulation of May 20, 1975; 40 CFR 419.15; 40 FR 21950.

27. Engineering Science, Inc. Texas. 1970. The Characteristics and Pollutional Problems Associated with Petrochemical Wastes. Prepared for the Federal Water Pollution Control Administration. U.S. Government Printing Office. Washington, D.C.

28. Institute of Gas Technology. 1975. An Overview of the New England Gas Industry. Gas Industry Development in New England, Analysis of Alternatives. Part I. Energy Program Technical Report: 75-9. New England Regional Commission. Boston, Massachusetts.

29. El Paso Alaska Company. 1974. Application of El Paso Alaska Company for a Certificate of Public Convenience Environmental Report. Volume III. Prepared for the Federal Power Commission.

30. Arthur D. Little, Inc. 1975. Gas Industry Development in New England: Analysis of Alternatives, Parts I, II, III. Energy Program Technical Report 75-9. New England Regional Commission. Boston, Massachusetts.

31. Chapman, C. 1968. Channelization and Spoiling in Gulf Coast and South Atlantic Estuaries. In Proceedings of the 1st Marsh and Estuary Management Symposium, July 19-20, 1967, Louisiana State University. Baton Rouge, Louisiana.

32. LaRoe, E.T. 1977. Dredging--Ecological Impacts. In Coastal Ecosystems Management: A Technical Manual for the Conservation of Coastal Zone Resources. John Wiley and Sons, Interscience, New York.

33. U.S. Army Corps of Engineers. 1969. Dredging and Water Quality Problems in the Great Lakes: Summary Report. Department of the Army, Corps of Engineers. Buffalo District, New York.

34. Harrison, J., R.L. Montgomery, and F.H. Griffis, Jr. 1974. Problem Identification and Assessment for the Corps of Engineers Dredged Material Research Program. Miscellaneous Paper D-74-12, U.S. Army Engineer Waterways Experiment Station. Vicksburg, Mississippi.

35. Henningson, Durham, and Richardson, Inc. 1975. Preliminary Feasibility Study for Sampit River Channel Development. Prepared for the City of Georgetown, South Carolina.

36. Griffin, G.M. 1976. Dredge-fill in the Coral Reef Tract of the North Florida Keys. In Specialty Conference on Dredging and Its Environmental Effects. American Society of Civil Engineers. New York.

37. Kaplan, E.H., J.R. Welker and M.G. Kraus. 1974. Some Effects of Dreding on Populations of Macrobenthic Organisms. Fishery Bulletin, Volume 72, Number 2.

38. U.S. Environmental Protection Agency. 1971. Water Quality Considerations for Construction and Dredging Operations. Water Quality Office, Southeast Region, Atlanta, Georgia.

39. Johnson, L.E. and W.V. McGuinness, Jr. 1975. Guidelines for Material Placement in Marsh Creation. CEM Report 4165-519, Center for the Environment and Man, Inc. Hartford, Connecticut (draft).

40. Shanks, L. U.S. Fish and Wildlife Service, Department of Interior. NSTL Station, Mississippi. Personal communication, 1975.

41. Murphy, W.L., and T.W. Zeigler. 1974. Practices and Problems in the Confinement of Dredged Material in Corps of Engineers Projects. Technical Report No. D-74-2. U.S. Army Engineer Waterways Experiment Station. Vicksburg, Mississippi.

42. Gagliano, S.M. 1973. Canals, Dredging, and Land Reclamation in the Louisiana Coastal Zone. Hydrologic and Geologic Studies of Coastal Louisiana. Report No. 14. Center for Wetland Resources. Louisiana, Report No. 14. Center for Wetland Resources, Louisiana State University. Baton Rouge, Louisiana.

43. U.S. Army Corps of Engineers. 1975. Permits for Activities in Navigable Waters or Ocean Waters. Federal Register. Volume 40, Number 144, Part IV (July 25, 1975).

44. U.S. Fish and Wildlife Service. 1975. Guidelines for Review of Fish and Wildlife Aspects of Proposals in or Affecting Navigable Waters. Federal Register. Volume 40, Number 231, Part IV (Dec. 1975).

45. Department of Ecology. 1972. Final Guidelines Shoreline Management Act of 1971. WAC 173-16-010 through WAC 173-16-200. State of Washington. Olympia, Washington.

46. Marine Resources Division. 1974. Guidelines for Coastal Wetlands Developments. South Carolina Wildlife and Marine Resources Department. Charleston, South Carolina.

47. Power, G. 1975. Watergate Village: 'A Case Study of a Permit Application for A Marina Submitted to the U.S. Army Corps of Engineers. Coastal Zone Management Journal. Volume 2, Number 2.

48. Southern Maine Regional Planning Commission and the State Planning Office. 1973. Model Zoning Ordinance. State of Maine, Augusta, Maine.

49. Roberts, M.F. 1971. Tidal Marshes of Connecticut. The Connecticut Arboretum. Report Series No. 1. Connecticut College, New London, Connecticut.

50. Gantt, L. N.D. Ecological Considerations Regarding the Use of Bulkheads and Rip-rap in the Chesapeake Bay Estuary for Shore Erosion Control. U.S. Fish and Wildlife Service Paper (unpublished). Annapolis, Maryland.

51. U.S. Army Corps of Engineers. 1971. Shore Protection Guidelines. In National Shoreline Study. Volume I. U.S. Government Printing Office. Washington, D.C.

52. Giannio, S.P. and H. Wange. 1974. Engineering Considerations for Marinas in Tidal Marhes. College of Marine Studies, University of Delaware. Newark, Delaware.

53. Savage, T. 1972. Florida Mangroves as Shoreline Stabilizers. Florida Department of Natural Resources. Professional Paper Series No. 19. St. Petersburg, Florida.

54. Kuenzler, E.J. 1974. Mangrove Swamp Systems. In Coastal Ecological Systems of the United States. Volume I. The Conservation Foundation. Washington, D.C.

55. Pilkey, O.H.,Jr. H. Pilkey, Sr. and R. Turner. 1975. How to Live With an Island. A Handbook to Bogue Banks, North Carolina. North Carolina Department of Natural and Economic Resources. Raleigh, North Carolina.

56. Colonell, J.M. 1977. Beach Protection. In Coastal Ecosystems Management: A Technical Manual for the Conservation of Coastal Zone Resources. John Wiley and Sons, Interscience. New York.

57. Hayes, M.O. and J.C. Boothroyd. 1969. Storms as Modifying Agents in the Coastal Environment. In Coastal Environments: NE Mass. and N.H. Contribution No. CRG. University of Massachusetts. Amherst, Massachusetts.

58. Shepard, F.P. 1969. The Earth Beneath the Sea. Atheneum Press. New York.

59. Brunn, P. and F. Gerritsen. 1960. Stability of Coastal Inlets. North-Holland Publishing Company. Amsterdam.

60. Goldsmith, V. and J.M. Colonell. 1970. Effects of Non-uniform Wave Energy in the Littoral Zone. In Proceedings of the Twelfth Conference on Coastal Engineering. Volume 2. American Society of Civil Engineers. New York.

61. Clark, J. 1977. Coastal Ecosystems Management: A Technical Manual for the Conservation of Coastal Zone Resources. John Wiley and Sons, Interscience. New York.

62. Godfrey, P.J. 1970. Oceanic Overwash and Its Ecological Implications on the Outer Banks of North Carolina. National Park Service, U.S. Department of Interior. Washington, D.C.

63. Dolan, R. 1973. Barrier Islands: Natural and Controlled. In Coastal Geomorphology. State University of New York. Binghamton, New York.

64. Davies, D.C., E.W. Axelrod, and J.S. O'Connor. 1974. Erosion of the North Shore of Long Island. Technical Report Series No. 18. Marine Sciences Research Center. State University of New York. Stony Brook, New York.

65. U.S. Army Corps of Engineers. 1973. Shore Protection Manual. U.S. Army Coastal Engineering Research Center. Ft. Belvoir, Virginia.

66. Michigan Department of Natural Resources. 1973. Natural Resources: A Plan for Michigan's Shorelands. Lansing, Michigan.

67. Clark, J. 1974. Rookery Bay: Ecological Constraints on Coastal Development. Final Report. Rookery Bay Land Use Studies. The Conservation Foundation. Washington, D.C.

68. U.S. Soil Conservation Service. 1975. Guidelines for Soil and Water Conservation in Urbanizing Areas of Massachusetts. SCS, U.S. Department of Agriculture. Amherst, Massachusetts.

69. Office of Water Program Operations. 1973. Comparative Costs of Erosion and Sediment Control, Construction Activities. Environmental Protection Agency, Report No. EPA-430/9-73-016. U.S. Government Printing Office. Washington, D.C.

70. U.S. Soil Conservation Service. 1972. Minimizing Erosion in Urbanizing Areas: Guidelines, Standards and Specifications. U.S. Department of Agriculture. Madison, Wisconsin.

71. Tourbier, J. and R. Westmacott. 1974. Water Resources Protection Measures in Land Development--A Handbook: Water Resources as a Basis for Comprehensive Planning and Development of the Christina River Basin. A Prototype Project, Phase II. Water Resources Center, University of Delaware. Newark, Delaware.

72. Veri, A.R., et al. 1975. Environmental Quality by Design: South Florida. University of Miami Press. Coral Gables, Florida.

Conner, W.H., et al. 1976. Oil and Gas Use Characterization, Impacts and Guidelines. Sea Grant Publication No. LSU-T-76-006. Center for Wetland Resources, Louisiana State University. Baton Rouge, Louisiana.

74. Clark, J. 1976. The Sanibel Report: Formulation of a Comprehensive Plan Based on Natural Systems. The Conservation Foundation. Washington, D.C.

75. Carroll, J.D., Jr. 1977. Personal communication concerning FWS letter of July 22, 1960 to U.S. Army Corps of Engineers on Sanibel bridge-causeway.

76. Coastal Environments, Inc. 1973. Environmental Considerations, Interstate I-410. Report prepared for Louisiana Department of Highways. Baton Rouge, Louisiana.

77. U.S. Department of Transportation. 1975. Preservation of the Nation's Wetlands. Order 5660.1 (5-21-75). Washington, D.C.

78. U.S. Department of Transportation, U.S. Coast Guard. October 10, 1974. Draft Environmental Impact Statement for Proposed Fixed Highway Bridge across Station Creek, Mile 2.6, Beaufort County, S.C., for Access from St. Helena Island to a Planned Residential Development on St. Phillips Island. U.S. Coast Guard. Washington, D.C.

79. Shanks, L. 1976. U.S. Fish and Wildlife Service, Department of the Interior, NSTL Station, Mississippi. Personal communication.

80. Copeland, B.J. 1974. Impounded Systems. In Coastal Ecological Systems of the United States. Volume III. The Conservation Foundation. Washington, D.C.

81. Taylor, W. N.D. Taylor, Wiseman and Taylor, Moorestown, N.J. Personal communication. 1975.

82. Pope, R.M. and J.G. Gosselink. 1973. A Tool for Making Management Decisions in the Coastal Zone. Coastal Zone Management Journal, Volume 1, Number 1.

83. Texas Transportation Institute. 1973. Transportation in the Texas Coastal Zone. Division of Planning Coordination, Office of the Governor. Austin, Texas.

84. U.S. Department of the Interior. 1970. The National Estuarine Pollution Study. U.S. Senate, 91st Congress, 2nd Session. Document No. 91-58. U.S. Government Printing Office. Washington, D.C.

85. Seckler, D. ed. 1971. California Water. University of California Press. Berkeley, California.

86. McGuinness, W.V., Jr and R. Patchai. 1972. Integrated Water Supply and Waste Water Disposal on Long Island. CEM-4103-456. The Center for the Environment and Man, Inc. Hartford, Connecticut.

87. U.S. Department of Interior, U.S. Geological Survey. 1973. Resources and Land Information for South Dade County, Florida. Geological Survey Investigation I-850. U.S. Government Printing Office. Washington, D.C.

88. Fisher, W.L. 1973. Natural Hazards in Land Use. TSNL Review, Volume 1, Number 1. Texas System of Natural Laboratories, Inc. Austin, Texas.

89. Marshall, A.F., Jr. February, 1973. How Much More Will Houston Sink? The Slide Rule. Volume 33, Number 2. Houston Engineering and Scientific Society. Houston, Texas.

90. Texas Department of Public Safety. 1974. If a Hurricane Strikes... Hurricane Awareness Program Bulletin. Division of Emergency Services. Austin, Texas.

91. Office of Water Programs Operations. 1974. Secondary Treatment of Municipal Ocean Discharges. Task Force Report (draft). Environmental Protection Agency. Washington, D.C.

92. National Association of Counties/Research Foundation. Community Action Program for Water Pollution Control. Washington, D.C.

93. Committee on Chemistry and Public Affairs. 1969. Cleaning Our Environment, The Chemical Basis for Action. American Chemical Society. Washington, D.C.

94. McNulty, J.K., W.H. Lindall, Jr. and J.E. Sykes. 1972. Cooperative Gulf of Mexico Estuarine Inventory and Study. Florida: Phase I, Area Description. National Marine Fisheries Service Circular No. 368. National Oceanic and Atmospheric Administration, U.S. Department of Commerce. Washington, D.C.

95. Martin, D.M. and D.R. Goff. N.D. The Role of Nitrogen in the Aquatic Environment. Department of Limnology, Academy of Natural Science of Philadelphia. Philadelphia, Pennsylvania.

96. Champ, M.A. 1975. Nutrient Loading in the Nation's Estuaries. A Report to Congress. American University. Washington, D.C.

97. Pearson, E.A. February, 1975. Estuarine Wastewater Management. In The Estuarine Pollution Conference. Pensacola, Florida. Environmental Protection Agency. Washington, D.C.

98. National Environmental Research Center. 1974. Feasibility of Overland Flow for Treatment of Raw Domestic Wastewater. Environmental Protection Agency. Washington, D.C.

99. National Academy of Sciences--National Academy of Engineering. 1970. Waste Management for the Coastal Zone: Concepts for the Assessment of Ocean Outfalls. Washington, D.C.

100. Water Quality Office. 1971. A Primer on Waste Water Treatment. Environmental Protection Agency. U.S. Government Printing Office. Washington, D.C.

101. Council on Environmental Quality. U.S. Environmental Protection Agency. 1974. Municipal Sewage Treatment. Washington, D.C.

102. Pound, C.E. and R.W. Crites. 1973. Wastewater Treatment and Reuse by Land Application, Volume 1: Summary. Prepared for the Office of Research and Development, Environmental Protection Agency. Washington, D.C.

103. Bender, W.H. 1971. Soils and Septic Tanks. Agricultural Information Bulletin 349. U.S. Department of Agriculture, Soil Conservation Service. Washington, D.C.

104. Goldman, H.B. 1974. Hayward Shoreline Environmental Analysis. Hayward Area Shoreline Planning Agency. San Francisco, California.

105. Ketelle, M. 1972. Physical Considerations for the Location of Septic Disposal Systems. An Inland Lake Renewal and Shoreland Management Demonstration Project, University of Wisconsin Extension. Madison, Wisconsin.

106. Minear, R.A. and J.W. Patterson. N.D. Septic Tanks and Groundwater Pollution. Department of Environmental Engineering, Illinois Institute of Technology. Chicago, Illinois.

107. U.S. Department of Interior, Bureau of Land Management. 1976. Draft Environmental Statement Proposed 1977 Outer Continental Shelf Oil and Gas Lease Sale Offshore the North-Atlantic States OCS Sale No. 42. Bureau of Land Management. Washington, D.C.

108. Anonymous. 1974. Directional Drilling Adopted for Pipe Line River Crossing. Pipe Line Industry. Volume 4, Number 3. Houston, Texas.

109. Mallory, C.W. 1973. The Beneficial Use of Storm Water. Prepared for the Office of Research and Monitoring, Environmental Protection Agency. Washington, D.C.

110. Black, Crow and Eidsness - Jordon, Jones and Goulding. 1975. Nonpoint Pollution Evaluation, Atlanta Urban Area. Report submitted to Savannah District Corps of Engineers. Savannah, Georgia. For Metropolitan Atlanta Water Resources Study Group. Contract No. DACW 21-74-C-0107. Gainesville, Florida.

111. Sartor, J.D. and G.B. Boyd. 1972. Water Pollution Aspects of Street Surface Contaminants. Environmental Protection Technical Series. Report No. EPA R2-72-081. Environmental Protection Agency. Washington, D.C.

112. Vitale, A.M. and P.M. Sprey. 1974. Total Urban Population Loads: The Impact of Storm Water. Report submitted to the Council on Environmental Quality. Enviro-Control, Inc. Rockville, Maryland.

113. Anonymous. June 9, 1974. The Great South Bay. Newsday: A Special Report. Garden City, New York.

114. U.S. Congress. October 18, 1972. Federal Water Pollution Control Act Amendments of 1972. P.L. 92-500. 92nd Congress, S.2770. Washington, D.C.

115. Stevens, R.M. 1972. Green Land--Clean Streams. Center for the Study of Federalism, Temple University. Philadelphia, Pennsylvania.

116. Burke, R.,III. 1971. A Survey of Available Information Describing Expected Constituents in Urban Surface Runoff; with Special Emphasis on Gainesville, Florida. Occasional paper. University of Florida, Department of Environmental Engineering. Gainesville, Florida.

117. U.S. Department of Agriculture, Soil Conservation Service. 1975. Urban Hydrology for Small Watersheds. SCS Technical Release No. 55. Soil Conservation Service. Washington, D.C.

118. Office of Planning and Budget, State of Georgia. 1974. Petroleum Refinery Feasibility Study of Coastal Georgia. Atlanta, Georgia.

119. Hughes, G.M. and K. Cartwright. 1972. Scientific and Administrative Criteria for Shallow Waste Disposal. Civil Engineering-ASCE, Volume 42, Number 3.

120. Feibusch, H.A. February, 1977. Solid Waste Disposal and Its Relationship to Estuarine Pollution. In Estuarine Pollution. Proceedings of a Conference held in Pensacola, Florida. Environmental Protection Agency. Washington, D.C.

121. American Chemical Society. 1972. Sanitary Landfill: Alternative to the Open Dump. Environmental Science and Technology. Washington, D.C.

122. Wingerter, E.J. 1972. Sanitary Landfill--A Survey of State Land Disposal Regulations. National Solid Wastes Mangement Association. Technical Bulletin. Volume 3, Number 3. Washington, D.C.

123. Schneider, W.J. 1970. Hydrologic Implications of Solid Waste Disposal. U.S. Geological Survey, Geological Survey Circular No. 601-F. Washington, D.C.

124. Office of Water Program Operations. 1973. Processes, Procedures and Methods to Control Water Pollution from Subsurface Excavations (draft). Environmental Protection Agency, Water Quality and Non-Point Source Control Division. Washington, D.C.

125. Sorg, T.J. and H.L. Hickman, Jr. 1970. Sanitary Landfill Facts. Public Health Service. U.S. Department of Health, Education, and Welfare, Bureau of Solid Waste Management. U.S. Government Printing Office. Washington, D.C.

126. Molz, F.J., S.R. Van Fleet, and V.D. Browning. 1974. Transpiration Drying of Sanitary Landfills. Ground Water. Volume 12, Number 6.

127. Van Tassel, A.J. ed. 1970. Environmental Side Effects of Rising Industrial Output. Heath Lexington Books. Lexington, Massachusetts.

128. Office of Water Planning and Standards. 1976. Overview. In Estuarine Pollution Control and Assessment, Proceedings of a Conference. Volume 1. Environmental Protection Agency. Washington, D.C.

129. Bryan, G.W. 1971. The Effects of Heavy Metals (Other Than Mercury) on Marine and Estuarine Organisms. Proceedings of the Royal Society of London. Volume 177, Number 1048.

130. Hann, R.W.,Jr. 1976. Industrial Waste Pollution and Gulf Coast Estuaries. In Estuarine Pollution Control Assessment. Volume 1. Environmental Protection Agency, Office of Water Planning and Standards. Washington, D.C.

131. Gray, J.S. and R.J. Ventilla. 1973. Growth Rates of a Sediment-living Marine Protozoan as a Toxicity Indicator of Interacting Heavy Metals. Ambio. Volume 2, Number 4.

132. Vernberg, W.B. and J. Vernberg. 1972. The Synergistic Effects of Temperature, Salinity and Mercury on Survival and Metabolism of the Adult Fiddler Crab, Uca Putilator. Fishery Bulletin. Volume 70.

133. Ewing, R.C. January 21, 1974. What Refiners Are Doing to Conserve Energy and Water. Oil and Gas Journal. Volume 72, Number 3.

134. U.S. Atomic Energy Commission. 1972. Final Environmental Statement--Shoreham Nuclear Power Station. Washington, D.C.

135. Atomic Energy Commission. 1972. Draft Environmental Impact Statement San Onofre Nuclear Generating Station Units 1 and 2. U.S. Atomic Energy Commission. Washington, D.C.

136. State of Maryland. Record of the Maryland Power Plant Siting Act. Volume 1. Maryland Department of Natural Resources. Annapolis, Maryland.

137. Kolflot, T.D. January 13-14, 1973. Cooling Towers--State of the Art. Paper given at U.S. Department of the Interior--Atomic Industrial Forum Seminar, Washington, D.C.

138. Clark, J.R. and W. Brownell. 1973. Electric Power Plants in the Coastal Zone: Environmental Issues. Special Publication No. 7. American Littoral Society. Highlands, New Jersey.

139. Provost, M.W. 1977. Mosquito Control. In Coastal Ecosystem Management: A Technical Manual for the Conservation of Coastal Zone Resources. John Wiley and Sons, Interscience. New York.

140. Ferrigno, F., L.G. MacNamara, and D.M. Jobbins. 1969. Ecological Approach for Improved Management of Coastal Meadowlands. In Proceedings of the 56th Annual Meeting, New Jersey Mosquito Extermination Association. Atlantic City, New Jersey.

141. Darnell, R.M., et al. 1976. Impacts of Construction Activities in Wetlands of the United States. Tereco Corporation. Environmental Protection Agency, Office of Research and Development. Corvallis, Oregon.

142. Robas, A.K. 1970. South Florida's Mangrove-Bordered Estuaries: Their Role in Sport and Commercial Fish Production. Sea Grant Information Bulletin No. 4. University of Miami. Coral Gables, Florida.

143. Bourn, W.S. and C. Cottam. 1950. Some Biological Effects of Ditching Tidewater Marshes. Fish and Wildlife Service Research Report No. 19. U.S. Fish and Wildlife Service. Washington, D.C.

144. Delaware State Planning Office. Lewes CCD Pilot Study: Wetlands. Working Paper No. 9. Delaware State Planning Office. Dover, Delaware.

145. Kunzler, E.J. and H.L. Marshall. 1973. Effects of Mosquito Control Ditching on Estuarine Ecosystems. Water Resources Research Institute, University of North Carolina. Raleigh, North Carolina.

146. Ferrigno, F. and D.M. Jobbins. 1968. Open Marsh Management. In Proceedings of the 55th Annual Meeting, New Jersey Mosquito Extermination Association. Atlantic City, New Jersey.

147. Ferrigno, F., P. Slavin, and D.M. Jobbins. N.D. Salt Marsh Water Management for Mosquito Control. New Jersey Division of Fish, Game and Shellfisheries. Trenton, New Jersey.

148. Bodola, A. 1970 An Evaluation of the Effectiveness of Natural Pools, Blind Sumps and Champagne Pools in Reducing Mosquito Production on a Salt Marsh. In Proceedings of the 57th Annual Meeting, New Jersey Mosquito Extermination Association. Atlantic City, New Jersey.

149. Ferrigno, F. 1970. Preliminary Effects of Open Marsh Water Management on the Vegetation and Organisms of the Salt Marsh. In Proceedings of the 57th Annual Meeting, New Jersey Mosquito Extermination Association. Atlantic City, New Jersey.

150. Ferrigno, F. N.D. New Jersey Division of Fish, Game and Shellfisheries. Various communications.

151. Boseman, D. 1974. Impoundment. In R.C. Axtell, ed., Training Manual for Mosquito and Biting Fly Control in Coastal Areas. University of North Carolina Sea Grant Program. Raleigh, North Carolina.

152. Provost. M.W. 1968. Managing Impounded Salt Marsh for Mosquito Control and Estuarine Resources Conservation. In Proceedings of the Marsh and Estuarine Management Symposium, July 19-20, 1967, Louisiana State University. Baton Rouge, Louisiana.

153. Provost, M.W. 1969. Ecological Control of Salt Marsh Mosquitoes with Side Benefits to Birds. In Proceedings of the Tall Timbers Conference on Ecological Animal Control by Habitat Management. Tall Timbers Research Station. Tallahassee, Florida.

154. American Cyanamid Company. 1967. Technical Information: Abate Mosquito Larvacide and Insecticide. Princeton, New Jersey.

155. New Jersey Agricultural Experiment Station--Cook College. 1975. Insecticides for Mosquito Control in New Jersey. Rutgers University. New Brunswick, New Jersey.

156. Coppage, D.L. and T.W. Duke. N.D. Effects of Pesticides in the Estuaries along the Gulf and Southeast Atlantic Coast. In Proceedings of the 2nd Gulf Coast Conference on Mosquito Suppression and Wildlife Management, October 20-22, 1971. New Orleans, Louisiana.

157. U.S. Department of the Interior. 1972. Fish and Wildlife and Pesticides. GPO 917-905. U.S. Government Printing Office. Washington, D.C.

158. Butler, P.A. 1966. The Problem of Pesticides in Estuaries. American Fisheries Society. Special Publication Number 3.

159. Lincer, J.L. 1977. Toxic Substances. In Coastal Ecosystem Management: A Technical Manual for the Conservation of Coastal Zone Resources. John Wiley and Sons, Interscience. New York.

160. Eisler, R. 1970. Acute Toxicity of Organochlorine and Organophosphorus Insecticides to Estuarine Fishes. Bureau of Sport Fishery and Wildlife. Technical Paper No. 46. Washington, D.C.

161. Nichols, L.G. 1958. Erosion of Canal Banks on the Rockefeller Wildlife Refuge. Louisiana Wildlife and Fisheries Commission, Refuge Divison. New Orleans, Louisiana.

162. Nicholas, L.G. 1959. Rockefeller Refuge Levee Study. Technical Report. Louisiana Wildlife and Fisheries Commission, Refuge Division. New Orleans, Louisiana.

163. Segall, R.A. 1975. Engineering Properties of Peats. Unpublished Manuscript. Louisiana State University, Center for Wetland Resources. Baton Rouge, Louisiana.

164. Louisiana Advisory Commission on Coastal and Marine Resources. 1973. Louisiana Wetlands Prospectus. Louisiana State University. Baton Rouge, Louisiana.

165. U.S. Department of Interior, Bureau of Land Management. 1976. Final Environmental Statement Proposed 1976 Outer Continental Shelf Oil and Gas Lease Sale Lower Cook Inlet. Volume 1. Bureau of Land Management. Washington, D.C.

166. Farrington, J.W. 1977. Oil Pollution in the Coastal Environment. In Estuarine Pollution Control and Assessment, Volume II. Proceedings of a Conference, February 11-13, 1975, Pensacola, Florida. Environmental Protection Agency. Washington, D.C.

167. Kifner, J. January 10, 1977. Tanker Losses Set Record in '76 Period. The New York Times. New York, New York.

168. Milius, P. January 9, 1977. Globally, Liberia's Merchant Fleet Is As Safe As Most. The Washington Post. Washington, D.C.

169. U.S. Department of Commerce. U.S. Maritime Administration. 1973. Draft Environmental Impact Statement, Maritime Administration Tanker Construction Program. U.S. Maritime Administration. Washington, D.C.

170. U.S. Department of Transportation, U.S. Coast Guard. 1975. Final Environmental Impact Statement, Deepwater Port Regulations. U.S. Coast Guard, Office of Marine Environment and Systems. Washington, D.C.

171. Marine Ecosystems Analysis Program. 1976. Hydrocarbons in the Ocean. Prepared for the National Oceanic and Atmospheric Administration. Washington, D.C.

172. Biggs, R.B. 1976. The Effects of Industrialization on the Estuary. In Estuarine Pollution Control and Assessment. Environmental Protection Agency, Office of Water Planning and Standards. Washington, D.C.

173. Moore, S.F. and R.L. Dwyer. 1972. A Preliminary Assessment of the Environmental Vulnerability of Machias Bay, Maine to Oil Supertankers. Massachusetts Institute of Technology. Cambridge, Massachusetts.

174. Nelson-Smith, A. 1970. The Problem of Oil Pollution of the Sea. Advances in Marine Biology. Volume 8.

175. U.S. Department of Interior, Bureau of Land Management. 1972. Evaluation of Environmental Impact, Proposed Trans-Alaska Pipeline. Volume 4. Bureau of Land Management. Washington, D.C.

176. California Coastal Zone Conservation Commissions. 1975. California Coastal Plan. Sacramento, California.

☆U.S. GOVERNMENT PRINTING OFFICE:1978 -745-421/ 4485 REGION NO. 4

Offshore Oil and
Living Resources