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Ecological and Environmental Impacts of Construction in the Coastal Zone

by

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ABSTRACT¹

Engineering works have been developed to alter the coastline to suit man's desires. However, imperfect knowledge of the nature of the forces acting in the coastal zone and their effects has resulted in unexpected or undesirable effects. Frequently such alterations create substantial conflicts between uses. For instance, use of the waters for waste disposal, resulting in pollution, directly conflicts with recreational and fishing uses. The filling of wetlands for use in residential, industrial, or port construction conflicts with wildlife and estuarine preservation, recreational uses, and fishing interests. Dredging of ship channels for navigation can alter salinity, temperature, and numerous other environmental parameters which conflict with almost all uses of the coastal zone area.

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¹The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

INTRODUCTION

The coastal zone is broadly defined as the area extending seaward to the limit of territorial space and landward to a distance which includes all land areas harboring activities directly dependant upon or influenced by the water.

In the U.S. this coastal zone contains about half of the population of the nation and most of the major cities. There are over 80,000 miles of shoreline in the U.S. coastal zone and many biologically important estuaries and wetlands.

Wetlands are those land and water areas subject to regular inundation by tidal, riverine, or lacustrine flowage. Generally included are inland and coastal shallows, marshes, mudflats, estuaries, swamps, and similar areas in coastal and inland waters. The wetlands produce a rich nutrient supply that supports a wealth of aquatic and semi-aquatic life, both in numbers and varieties. This wealth of life - particularly the fish, wildlife, and higher plants - is of tremendous interest to man for its esthetic, sport, and food value. The higher animal and plant forms are in turn dependent upon the microscopic forms for their life support systems. The world of animal and plant life is a world of energy and material transformation and cyclic phenomena, as life and death are continued.

Wetlands have been used by numberless individuals for various purposes. When drained they have provided rich tracts of farmland; when filled they have provided sites for homes, industry, and commerce. They have been mined for building materials, oil, sulfur, salts, and metals, and on occasions, have served as depositories for ever-increasing amounts of liquid and soil wastes. They have provided millions of people with a

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playground to enjoy nature and find excitement in fishing or hunting and other recreation at the edge of the water.

During the early years when America was first settled, there was an estimated 127 million acres of wetlands. Because of their accessibility to water transportation, these wetlands were targets for development. The Federal Swamp Acts of 1849, 1850, and 1869 paved the way for the transfer of nearly 65 million acres of wetlands to 15 states from federal to state administration in order to expedite their drainage, mostly for agricultural purposes. In the last wetlands survey conducted by the Fish and Wildlife Service of the U.S. Department of the Interior (USDI), 1955, it was reported that only an estimated 75 million acres remained. Of this total, 85% of the country's wetlands were inland freshwater areas, 2% were inland saline, 5% were coastal freshwater areas, and 7% were coastal saline areas. The smaller acreage of the coastal wetlands should not obscure the fact that they provide most of the food for marine life (1-10).

CHARACTERISTICS OF THE COASTAL ZONE ENVIRONMENT²

Marine Environment

Marine environments can be conveniently categorized into two major domains: the coastal ocean and the open ocean. The coastal ocean includes estuaries and adjacent wetlands, lagoons, the waters over the continental shelves, and many marginal seas. The open ocean is that part not significantly affected by its boundaries between the coastal and

² Abstracted from "Environmental impacts of Pipeline Rights-of-Way in the Coastal Zone", 67, Weed control Methods for Rights-of-Way Management, CRC Press, Boca Raton, FL, 1982

open ocean. Water, pollutants, and spilled oil can readily move from the coast to the open ocean or vice versa.

Open Ocean

Beyond the continental shelves, the ocean is relatively unaffected by its boundaries. There are no lateral restrictions, and the ocean bottom is some 4 to 6 km (2.5 to 4 mi) below the surface. Over most of the ocean, warm surface waters are separated from the cooler deep waters by the pycnocline, a rapid increase in density that more or less separates the surface ocean waters from the deeper waters. While the deeper waters are known to move sluggishly after forming in the polar regions (primarily the Antarctic) and to return to the surface about 600 to 1000 years later, they do not affect the fate or movement of petroleum spilled on the ocean surface. Therefore, the movements of the deep ocean waters can be ignored, as it is the ocean surface circulation that is important.

Away from the land masses that interrupt surface water movements, ocean currents are primarily directed east west. Only in the area of the boundaries are the currents deflected to the north or south forming major boundary currents. Open ocean currents generally move the waters at speeds of a few kilometers per day. In the boundary currents such as the Gulf Stream or the Kuroshio Current, the waters move at speeds of 10 to 100 km/day.

Winds blowing across the ocean set the surface waters in motion. In the open ocean where tidal currents are relatively weak, these wind drift currents comprise about 40% of the surface currents and are probably the most important factor contributing to the movement of oil spills. An oil slick at sea will commonly move at a speed of about 3 to 4%

of the wind speed. Because of these wind effects, oil spilled in the open ocean may be moved into the coastal ocean and eventually onto the shore or into wetland areas.

Coastal Ocean

The coastal ocean is the water adjacent to the shore; there the adjacent land boundary, fresh water runoff from the land, and local atmospheric conditions contribute significantly to the movement and mixing of the waters. The width of this zone is highly variable, and the outer boundary is not well defined. It may be quite narrow along coasts where the continental shelf is narrow and where oceanic conditions and the "permanent" currents come close to shore. Conversely, off a coast where the continental shelf is quite wide, the coastal ocean may be well over 100 mi wide. It is not, however, coincident with the continental shelf. Where the shelf is very narrow, the coastal ocean may extend beyond the shelf, and where the shelf is very wide, the coastal ocean may extend out from the shore for only a fraction of the shelf width. The critical features defining this zone are the dominance of boundary effects and of the transient local effects on the water movement.

There is considerable variation in the movement of the waters near the shore. Tidal currents are often strong; generally the strongest currents are near the shore. They generally parallel the coast and may be either oscillatory or rotary in character, depending on the local geography. Inshore from the point where surface waves break, a longshore current that parallels the shoreline usually develops. The current direction depends upon the angle at which waves approach the shore. For example, along a coastline oriented in a north-south direction, with the ocean to the east, waves approaching the shoreline from the north-east will produce a longshore current that flows southward.

Outside the surf zone, local winds and the salinity gradient, caused by runoff from the land, combine to dominate the nontidal current in the near-shore zone. Since the waves

breaking on a shoreline at any given time may have been for the most part generated by storm systems some distance away, the direction from which the waves approach the coast and the local wind direction are generally not correlated. Consequently, the direction of the flow inside the surf zone may be opposite to the direction of the currents seaward of the surf zone.

Along coasts having relatively large freshwater inflows to the ocean, such as the Atlantic coast of the U.S., the salinity, and generally the density, for the water increases with distance offshore. The average net nontidal flow in the near-shore zone will, along such coasts in the Northern Hemisphere, be directed such that the shoreline is to the right of an observer looking downstream. Such currents are particularly well developed along coasts to the right (looking seaward) of the mouths of major estuaries - southward from the mouth of the Chesapeake Bay, for example.

At any particular time, however, the currents in the coastal ocean may be dominated by the local wind or by density-induced effects resulting from the wind. Hence, an offshore wind will transport surface waters offshore, particularly a wind blowing at an angle to the shoreline such that an observer with his back to the wind has the shoreline on his left. Under these conditions, warmer surface waters are transported offshore, and the cooler subsurface waters from offshore are brought to the surface near shore, a process known as upwelling. The resulting density distribution will produce, in the Northern Hemisphere, a current flowing along the coastline with the shore to the left of the current (looking downstream).

Estuaries

Most of the existing ports and harbors in the world are located on estuaries. Despite their variety of shapes and sizes, estuaries commonly exhibit similar physical and biological processes. To understand the fate and effects of petroleum when spilled in these areas, it is first necessary to consider these processes.

An estuary is a semienclosed coastal body of water that has a free connection with the open sea and within which seawater is measurably diluted with freshwater derived from land drainage. Four types of estuaries are recognized: drowned river valleys, fjord-like estuaries, bar-built estuaries, and estuaries produced by tectonic processes.

Drowned river valleys are perhaps the most familiar, occurring along most of the U.S. Gulf and Atlantic coasts. Because they are generally confined to coastlines with relatively wide coastal plains, these waterways have also been called coastal plain estuaries. These estuaries are wide-spread throughout the world and are often the sites of major ports. Philadelphia on Delaware Bay and London on the Thames River estuaries are two examples.

Bar-built estuaries, such as Pamlico Sound, are usually shallow and often too small to serve as ports for modern tankers. Fjord-like estuaries, such as Puget Sound, and tectonically formed estuaries, such as San Francisco Bay, are more acceptable for tanker ports.

In a typical estuary, the salinity of the water increases with depth as well as in the seaward direction. There is usually a surface layer in which the vertical salinity change is small, an intermediate layer in which the salinity increases rather rapidly with depth, and a deep layer in which the rate of increase of salinity with depth is small, as in the surface layer. Vertical diffusive and advective mixing takes place between the surface and

bottom waters.

Tidal currents, ebb tides, and floods usually dominate in estuaries. Superimposed on the tidal currents is a net circulation pattern (known as the Estuarine circulation) in which there is a net seaward flow in the surface waters and a net flow from the mouth toward the head of the estuary in deeper waters. There is also a small net flow from the deeper layers to the surface layers. The volume of water flowing toward the head of the estuary (per unit time) decreases from the mouth to the head of the estuary, since water is simultaneously being moved upwards (entrained) from the deeper layers to the surface layers. Consequently, the amount of seaward flow of surface waters increases from the head toward the mouth of the estuary.

Being less dense than seawater, any crude oil or petroleum product spilled in an estuary moves with the surface waters in the net flow toward the mouth of the estuary. Mixing of the surface and subsurface waters leads to horizontal and vertical spreading. Soluble constituents will eventually be added to the deeper layers and have a net flow toward the head of the estuary. Floating oil is ultimately flushed from the estuary in the seaward flow of the surface layers or is washed ashore to be deposited on beaches or trapped in wetlands surrounding the estuary.

The basic estuarine circulation pattern prevails in most of the coastal ocean where the input of the freshwater from river runoff and rain exceeds the loss by evaporation from the surface. Thus, over the continental shelf, the surface waters generally have a net motion seaward, while the near bottom waters move generally toward the shore as well as moving along the coast.

Shores - Beaches and Wetlands

The shore is that strip of land bordering the ocean that is alternately exposed or covered by waves or by the changes in the water level due to the tide. Where wave action is relatively vigorous and the supply of sand is adequate, the shore is marked by a beach - a dynamic deposit of loose sand or gravel. In more protected areas, wetlands (either marshes or swamps) border the shoreline. In those areas where the land is rising due to mountain building or the recent retreat of the continental glacier, the shore may be marked by a rocky coastline, such as the New England coast (north of Cape Cod) or parts of the Pacific coast of the U.S.

Onshore winds and wave-induced water movements move spilled oil toward the shore. Indeed, some of the more dramatic effects of spilled oil have been observed along the shore and in wetlands subjected to large spills of oil such as the oil from the Torrey Canyon along the Cornish coast of Great Britain or the Brittany coast of France.

Rocky shores are typical of steeply sloping coastal areas where the sea acts directly on resistant rocks. In many of the areas used for supertanker ports (especially fjord-like estuaries), rocky shorelines are common, owing to the recent glaciation that provided the deep waters nearshore suitable for the deep draft vessels and also removed soils and unconsolidated deposits from the coastal areas. In such areas, marine organisms have typically attached themselves to the rocks which support extensive communities of marine animals and plants.

Where sands and gravels are more abundant, beaches form under the action of the waves. Built of loose sand or gravel, the beaches build outward and retreat in response to changing wave conditions. Relatively few organisms grow in or on the beaches, but they are not wholly devoid of life. On the lower parts of the beach where wave action is less vigorous, burrowing animals can usually be found.

Wetlands are low-lying coastal areas that are intermittently covered by tidal waters during the normal spring tides (the highest tides that occur every two weeks). Also included in the wetlands are the tidal channels through which the waters flow into the wetlands during a flooding tide and drain out again during an ebbing tide. Tidal marshes are typically covered by marine plants - either algal mats or various kinds of marine grasses, depending on the location of the marsh.

Some wetlands are protected from direct wave action by the topography of the shoreline or by barrier beaches. However, the relatively fine-grained sand and mud deposits in the marsh areas are stabilized by the growth of the plants which tend to trap not only sediment, but also floating debris, including petroleum. Thus, these marshes may be subjected to oil accumulation when the spills occur outside the marsh itself. The wetlands do provide a variety of uses for man and a range of approaches to the problems are required to protect their valuable functions as wetlands.

SUMMARY AND CONCLUSIONS

Wetlands are common along the Atlantic and Gulf coasts of the U.S., but also occur along the Pacific and Alaskan coasts as well. They are highly productive of plant material and thus are important sources of food for many marine organisms. Furthermore, they serve as home or nursery grounds for many species of marine organisms at some stage of their life cycle.

Wetlands are unlikely to serve directly as deepwater port areas; instead, they may be involved in pipeline construction from a port facility to onshore storage. Owing to their abundance along the Atlantic and Gulf coasts and the nature of water movements in them, wetlands are likely to be affected by oil spilled in the coastal waters or in harbors.

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