Shoreline Protection on Sand Beaches

Phase 1—Final Report

API TECHNICAL REPORT 1150-1
SEPTEMBER 2013

AMERICAN PETROLEUM INSTITUTE

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Executive Summary

- The behavior of oil washing onshore along beaches is dependent on the type and dynamics of the coastal setting. Sand beaches typically consist of ridges, flat berms and swales (runnels) that change constantly as sediments are reworked and redistributed by wave action.

- Under normal wave and tidal conditions, oil is deposited in the upper intertidal zone. However, during high wave-energy events and moderate storms, oil can be carried to the upper beach and deposited in berm runnels and at the base of dunes.

- During high wave and surge events accompanying large extra-tropical storms, tropical storms, and hurricanes, dune systems can be eroded and oil can be carried into back-barrier lagoons and wetlands.

- Temporary containment of oil along open beaches involves construction of ridges of sand and boom deployment. More robust structures include armored baskets, rip-rap revetments, and gravel and sediment berms.

- Containment of oil at breaches, in low-lying areas such as washovers, and small ephemeral channels (typically less than 200 m wide and 1 m deep) can initially rely on sand bags and barriers such as hard boom and Super Sacks, but the prevention of storm-induced incursion of oil requires the construction of bulkheads, rip-rap revetments or rock and sediment dams.

- Barricades across tidal channels prevent tidal exchange and likely would cause sediment deposition and a straightening of the shoreline, which may result in oil burial.

- Oil pooled adjacent to structures, particularly at barricaded channels, can be concentrated using sumps and removed with pumps or skimmers.

- The development of protection strategies and tactics includes consideration of the operational constraints and of the potential consequences of the planned activities. Some of the primary response considerations (Section 5) are identified to assist planners and strategists ensure that proposed actions are conducted in a responsible manner to minimize additional impacts to the environment, including human uses.

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Final Report

1 Introduction

Oil that reaches a sand beach following a spill onto water most frequently is deposited in the upper intertidal zone on falling tides. If water levels are high at the time oil washes ashore, because of spring tides or wind-induced surges, the oil can be deposited above the average high water level (HWL) in the supratidal zone (Figure 1.1) or can be carried across the beach into low-lying backshore areas such as wetlands, lagoons, salt ponds or estuaries.

Figure 1.1 *Sand beach backed by vegetated dunes. HWL = High (tidal) Water Level*

During elevated tide levels, one protection strategy to prevent oil from reaching these low-lying, and often environmentally sensitive, backshore areas is to construct a fixed or moveable barrier along the beach or across storm channels to contain the oil along the ocean shore.

The purpose of this study is to describe:

- The form and processes that characterize sand beaches. Sand beach forms include beaches backed by dunes or terrestrial environments and barrier islands and spits that are backed by wetlands, lagoons, salt ponds or estuaries. Shore zone processes are a combination of winds, waves and tides.
- Conditions during which oil can be carried over a beach into the supratidal or backshore zones.
- Strategies and tactics that can be used to intercept and contain oil as it overwashes beaches.
- Response considerations for the design and implementation of the protection strategies.

This report focuses on those strategies and tactics that can be used on sand beaches across low-lying areas, such as shallow storm passes, washover areas, and ephemeral channels. This report does not include possible plans for collecting or deflecting oil using boom at tidal inlets or in estuaries. Response strategies associated with the containment and control of oil on the waters of tidal inlets are the subject of a separate API report "*Tidal Inlet Protection Strategies (TIPS)*" (API, 2013b).

A companion Field Guide (API, 2013a) summarizes and illustrates the tactics described in this report.

2 Beach Character and Dynamics

Although barrier island and tidal inlet shorelines are in quasi-equilibrium with the tidal and wave energy conditions of that coast, they are highly dynamic systems due to the cyclic pattern of storm erosion and post-storm recovery and are constantly evolving in response to long-term trends of sea-level rise (SLR) and waning sediment supply. Along some coasts, such as Louisiana, the lack of new sediment sources coupled with high rates of SLR has led to the evolution of many low narrow transgressive barriers that are migrating onshore through washover processes, particularly during storms. The susceptibility of these barrier types to washovers and breaching and transport of oil into back-barrier bays and wetlands during an oil spill event makes them priority sites for oil containment and backshore protection.

There are many text books and published papers on sand beaches that provide additional material on beach character and shore-zone dynamics (e.g. Carter, 1988; Davis and FitzGerald, 2004; Hayes, 1979; Komar, 1998).

2.1 Beaches, Barrier Islands and Spits

Beaches, barrier islands and spits are ridges of sediment built by waves and wind above the *intertidal* zone. Barrier islands and spits typically parallel the coast and are separated from the mainland by a water body (lagoon or estuary) and/or wetland (marsh, mangroves).

Beaches, barrier islands and spits are created by the alongshore and/or onshore transport of sediment by waves, winds, and currents and may be separated from adjacent shorelines or from other barriers by tidal inlets that exchange tidal waters with back-barrier lagoons, bays and wetlands. The form and dynamics of tidal inlets and response strategies associated with containment and control of oil on the waters of the different types of inlets are the subject of a separate report (API, 2013b).

The form and character of a sand beach constantly changes on both long-term (years, decades, centuries) and short-term (hours, weeks, months) scales.

2.1.1 Long-term Dynamics

- The long-term dynamics and stability of sand beaches are related to sediment supply, rate of sea-level rise, storm magnitude and frequency, and other coastal processes that affect the region.

- Beaches with an abundant sand supply (alongshore or nearshore source) prograde seaward as sand accumulates in the intertidal and supratidial zones. Windblown sand creates dunes in the supratidal zone, which in turn can be stabilized by vegetation. Rising sea level and diminished sediment supplies can cause an entire beach or barrier system to migrate landward through time.

- Erosion of the beach or barrier takes place when the long-term supply of sand to the beach system is limited and/or when wave processes remove more sand from the system, either by alongshore transport or offshore transport, than is supplied.

- Long-term rates of change are a function of regional processes, so that sediment accumulation or erosion is more rapid in areas with high wave-energy levels associated with storm events or swell waves.

2.1.2 Short-term Dynamics

- Short-term dynamics are related to hourly, daily, weekly or seasonal changes in wave height and tidal water levels, and the effects of storm events, in particular during elevated storm surges.

- In the intertidal and subtidal zones, sands are in constant motion due to wave turbulence and currents caused by breaking and shoaling waves. Rates of transport or redistribution at any given time are a function of wave energy so that greater volumes of sediment are in motion as wave energy and breaker heights increase.

- Sand typically accumulates during periods of low wave heights and is eroded from the beach during high wave events (Figure 2.1). This “erosion” is usually temporary and the sand that had been transported offshore during storms is moved back onshore when depositional wave conditions return along the beach.

- Wave energy levels change daily and seasonally. The erosion/recovery cycle is common as a result of storm events and may extend over a period of days or even weeks. At locations where there are distinctive high and low wave-energy seasons, the cycle may be an annual pattern with narrow, steep beaches in one season and a wide, flat intertidal zone during the low-energy period.

- The zone in which waves actively rework and redistribute sediments changes as water levels and wave heights change. The intertidal zone is the “active” zone during low wave-energy periods and average or *neap tides*. Wave processes are active in the supratidal zone during periods of elevated water levels that result from high waves, *spring tides,* and/or *storm surges*. At these times, wave run-up and overwash can reach the dune zone or transport water across the entire barrier and into the back barrier lagoon or wetland.

2.1.3 Dunes

The wind transport of sediment in the supratidal zone frequently creates sand dunes that, particularly when vegetated, stabilize the beach system in this dynamic environment. During high spring tides or storm surges dunes prevent overwash (and the oil it can carry) from flowing into the backshore and adjacent lagoon and wetland regions. Storm overwashing of barriers occurs where dunes have been dismantled after extended periods of erosion. Likewise, storm waves can breach a dune ridge and overwash channels may be cut through the dune ridge(s) to the backshore.

2.1.4 Examples of Beach Forms

Beaches commonly experience erosional and depositional cycles as a function of storm processes and post-storm accretion. Longer-term trends are associated with seasonal changes in wave a climate such as along the California coast, where wide sandy beaches produced by accretionary summer wave conditions are replaced by narrow beaches caused by large, shorter period winter waves that erode beaches. In other areas, beaches are eroded during prolonged periods of storm activity such as occurs along the US East Coast that is influenced by late fall and winter extratropical storms and on the US Gulf Coast affected by winter frontal systems. Beaches generally accrete during the spring and summer in both these regions (Figure 2.2).

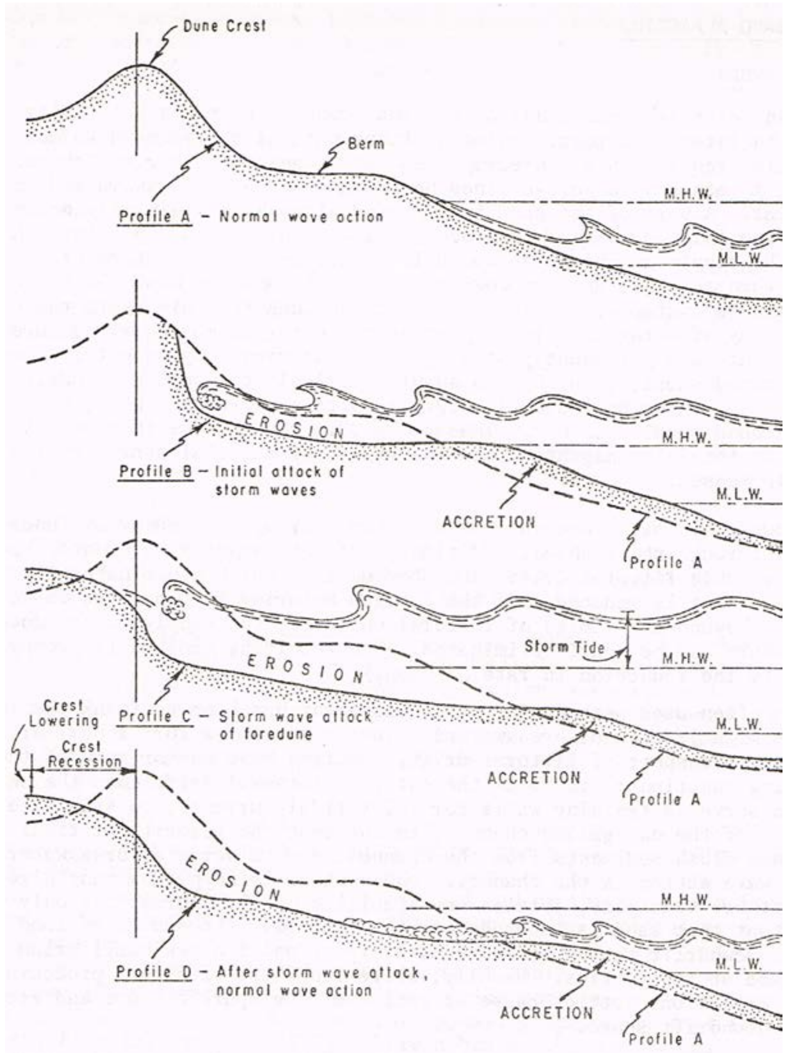


Figure 2.1 *Conceptual diagram showing (Profile A) a typical beach profile with a well-developed berm just above the high tide level and a convex intertidal profile. Profile B shows sand movement and changes in a beach profile as a result of storm erosion by waves, followed by erosion with a high, wind-induced water level (Profile C), and accretion after the storm by normal wave action (Profile D).*

Along the Gulf Coast, and to a lesser extent along the East Coast, beaches also undergo extensive erosion during the passage of hurricanes and tropical storms. As seen in Figure 2.2, Fourchon Beach, the central Louisiana coast experienced cyclic shoreline changes during 2010-2011, but was severely eroded during Tropical Storm Lee on 2 September 2011 when the beach retreated 50 m.

2.2 Oil Deposition

2.2.1 Supratidal Berms

Moderate to high-energy waves combined with elevated water levels that accompany high spring tides and storms can cause wave swash to flow across the berm crest and onto the supratidal berm, sometimes extending across the entire beach. During oil spill events, these conditions produce pooling of oil in low areas, such as berm runnels and at the base of the dunes.

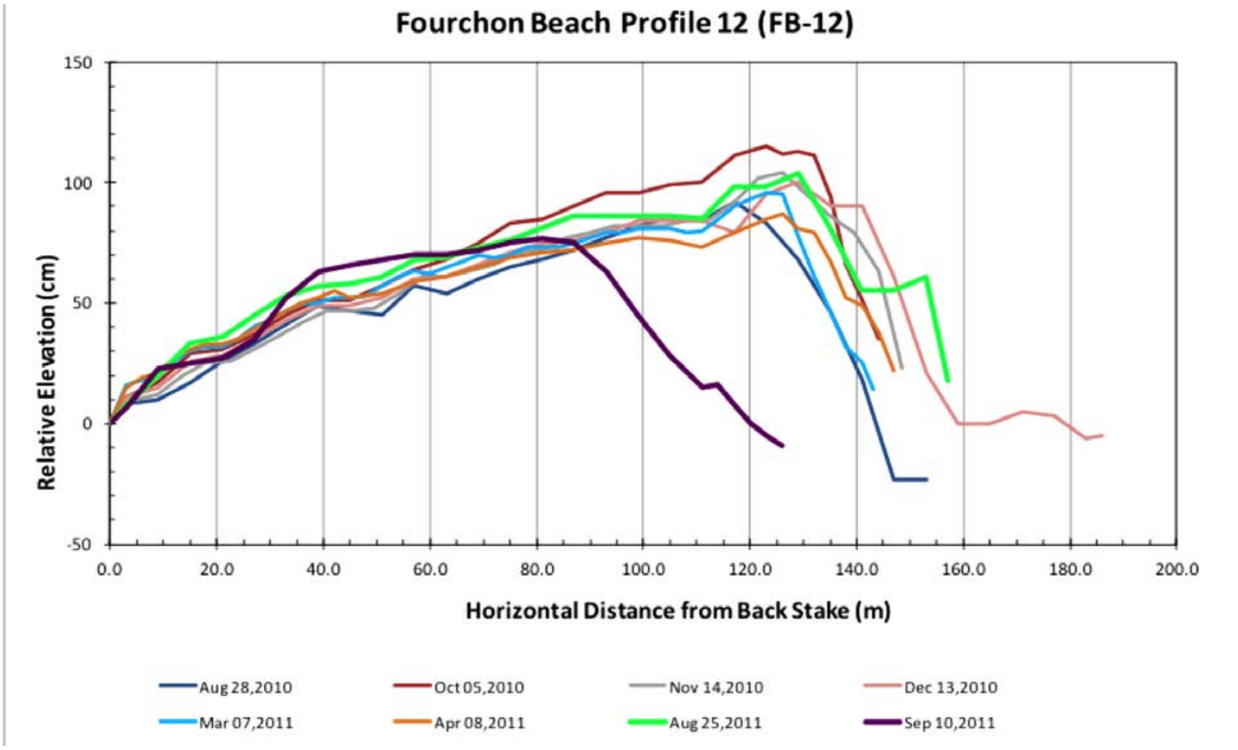


Figure 2.2 *Beach profile sweep zone of a station surveyed along Fourchon Beach, LA covering the August 2010 to September 2011 period. The profiles illustrate erosional-depositions changes resulting from seasonal frontal systems and post-storm recovery as well as the erosional effects of Tropical Storm Lee (2 Sept 2011).*

2.2.2 Across Barrier Beaches (Overwash)

Under non-storm conditions oil is typically stranded by falling tides in the intertidal zone. The oil may be refloated by subsequent rising tides and reworked into the sediments or transported away from the beach. The oil usually remains below the high water level (HWL), however, during spring high tides or periods of storm surges, oil can be washed into the supratidal zone or, during severe events, washed across the beach into sensitive backshore areas, such as wetlands, lagoons, ponds or rivers. Where the potential exists for oil to be transported to the backshore, either by broad overwash on low barriers or through overwash channels cut through dune ridges, strategies are designed to prevent the overwash process from occurring using different types of barriers based on the conditions of the area. This field guide focuses on those strategies and tactics that can be used on land to intercept and contain oil as it is washed ashore.

- Oil washed ashore is deposited below the HWL under normal tide and wave conditions.
- During spring high tides and low storm surges oil can be deposited in supratidal berm runnels and at the base of dunes.
- During intense storms, oil can be transported across low transgressive barriers and into washover cuts through dune ridges to back-barrier lagoons and wetlands.
- Strategies to prevent oil from reaching back-barrier settings rely on different types of barrier construction.

3 Response Strategies and Tactics

The typical elements of a beach are the *intertidal zone* (terms in *italics* are defined in Section 7) below the *High Water Level*, the *supratidal zone* and the *backshore*. In Figure 1.1 the backshore of this barrier beach is a continuous dune system. The continuity of many individual barriers is broken by shallow tidal passes and overwash channels that can exchange tidal waters with back-barrier lagoons and the open sea during high tide or storm surges. Overwash and ephemeral tidal channels present a critical potential pathway for oil to enter lagoons. The transport of oil through these channels is controlled by water depth, which affects the duration of tidal flow and the strength of the tidal currents.

The continuity of many barrier beaches also can be interrupted by permanent tidal inlets or passes that connect backshore lagoons to the open sea. Inlets provide an important potential oil pathway into tidal lagoons. The transport of oil through inlets is controlled by inlet size, tidal current velocity, and wave action. Protection, containment, and recovery strategies involve the use of floating boom to intercept, redirect or control the oil. These strategies and tactics are very different from those used on sand beaches to prevent oil washing over a beach and are the subject of a separate report (API, 2013b).

There are numerous oil spill response manuals and Job Aids that provide additional material on beach protection strategies and tactics and a few of these are listed in the Reference section (Section 6).

3.1 Shoreline Protection Objective

The objective of an on-land response to oil washing ashore is to intercept or contain and control oil to prevent waves or storm surges from over-washing a beach and carrying oil into backshore areas.

3.2 Shoreline Protection Strategies

Three strategic protection options to intercept or contain and control oil as it washes ashore are to:

a) Create a fixed barrier (sand dikes, bulkheads, armored baskets, rip-rap revetments, sand and gravel dams, etc.);

b) Deploy a moveable barrier or boom; and/or

c) Create a sump into which oil can flow for collection.

This report focuses on tactics that are specific to sand beaches and that are land-based. Manuals that provide additional material related to this topic include: API, 2001; Environment Canada, 2010; ExxonMobil, 2008; and NOAA 1992, 2010a, 2010b.

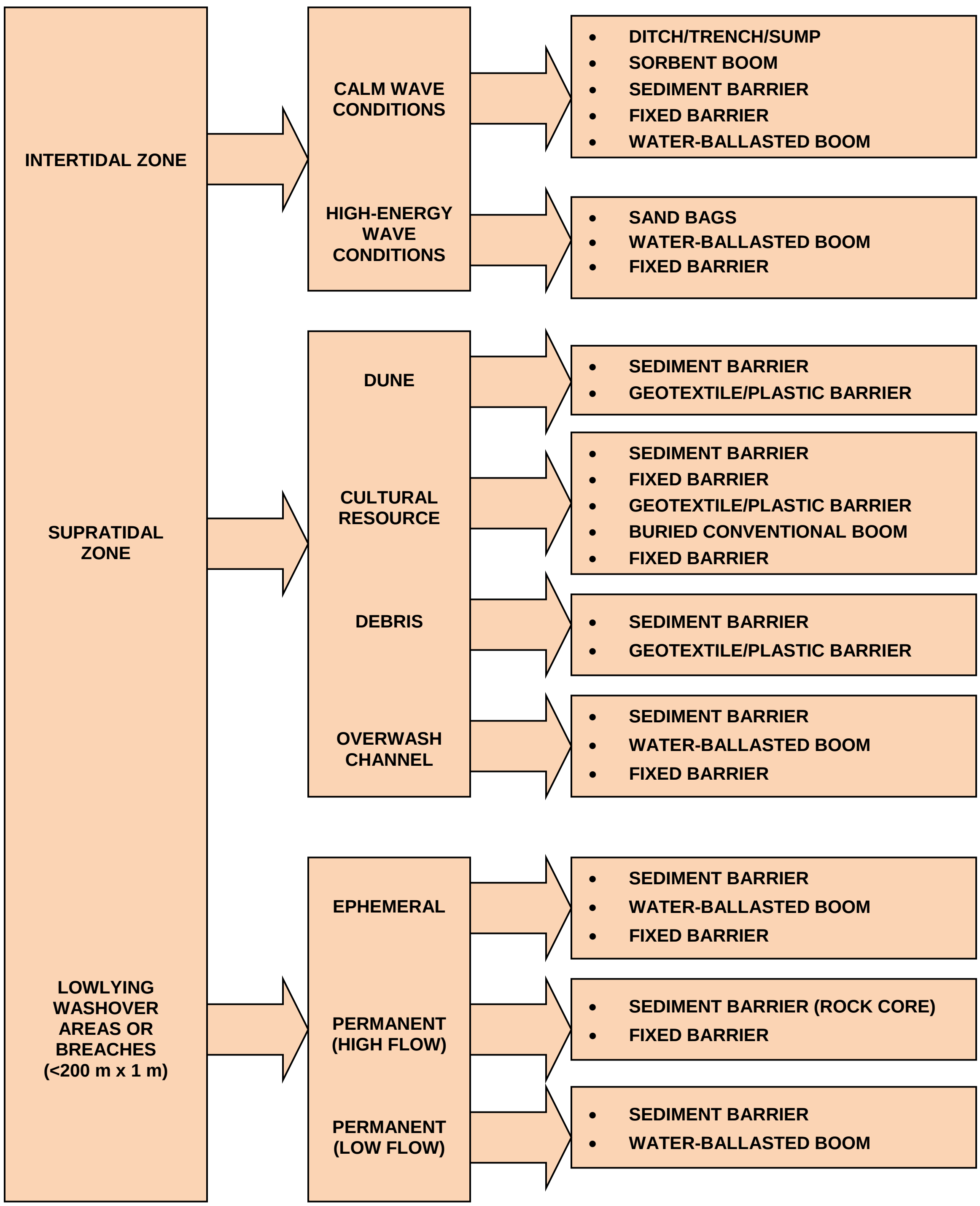
Section 3.3 provides a ***Decision Guide*** to assist with the selection of protection options for different sand beach environments. The guide is organized in terms of location on the shoreline, existing or anticipated wave energy, the feature of concern to be protected, and tidal channel or breach flow conditions. Options are based on typical responder experience and are intended to provide a starting point in the identification of appropriate tactics. Each situation is unique and must be assessed in consideration of the environmental conditions prevailing at the time of the response. Multiple or other related protection tactics, such as on-water recovery or diversion, may be appropriate to meet the needs of site-specific protection objectives.

Section 3.4 summarizes the ***primary characteristics for eight generic sand beach protection tactics***.

Section 3.5 identifies some of the key ***implementation considerations*** in the selection of the most appropriate tactic(s). Section 5.5.1 presents deployment and durability considerations; and Section 3.5.2 describes key operational factors in terms of labor requirements, safety, maintenance, waste and demob issues.

Section 3.6 provides ***illustrations*** of the eight generic shoreline protection options.

3.3 Sand Beach Protection Decision Guide



3.4 Shoreline Protection – Generic Tactic Descriptions

TACTIC	***DESCRIPTION***
FIXED BARRIERS AND DAMS	
Sediment Barriers or Dams	**Berms, ridges or sediment dams** are constructed, manually or mechanically, parallel to the water line to act as a barrier to water and oil washing over a beach. Generally, beach sediment would be used to construct this barrier, or material may be imported.
Sand Bags	**Sand bags** are used to create a barrier or dam. They may be filled on site with local sediment or with non-beach sediments. Typically canvas bags or sediment-filled, military-type, cellular fabric/wire mesh (e.g. armored baskets).
Geotextile or Plastic Barriers	**Flexible barriers** include a range of materials such as geotextiles, plastic sheets and silt screens, which are used to create a barrier or dam. They typically would be anchored and the base could be partially buried into the beach or, for some types of sensitive features, completely buried with sand.
Solid Barriers	Wood sheets, metal sheets, or other solid materials are used to create a barrier or dam. Solid barriers should have an underflow design where water flow/exchange is required. Can include a combination rubble and geotextile barrier.
MOVEABLE BARRIERS AND BOOMS	
Water-ballasted Booms	**Water-ballasted booms** include designs such as anchored, water-filled bladders or tubes or “shore-seal” boom that have an air chamber that sits on one or two water-filled tubes. Once deployed and anchored at the selected location, water is pumped into bottom chamber(s). For types with an upper air-filled bladder, this water acts as ballast when the boom is floating. When the boom is grounded, the flexible ballast chamber(s) follow the beach surface to form a seal. Alternatively the booms can be anchored so that they remain grounded on the beach surface and do not float.
Conventional Booms	**Conventional boom** is anchored on a beach with the skirt buried or partially buried in the sediment. Typically used to contain and control oil moving alongshore at the water line.
Sorbent Booms	**Sorbent boom** is constructed of a long, fabric sock (“sausage boom”) that encloses material that adsorbs oil but repels water. Unlike hard boom, sorbent boom does not have an attached skirt. **Snare boom** (or “sweep boom”) is constructed from a series of oleophilic polypropylene “pompoms” tied to a long line. Snare boom is anchored parallel to the water line to contain and adsorb oil on the water surface as it is washed ashore.
SUMPS	
Ditches or Trenches	**Collection sumps, ditches or trenches** are excavated, manually or mechanically, to collect oil as it washes ashore. Collection sumps can be installed independently or in conjunction with ditches or trenches and with one or more of the barrier and/or boom options.

3.5 Shoreline Protection Implementation

3.5.1 Deployment and Durability

TACTIC	*LOCATION*	*DEPLOYMENT*	*DURABILITY*	*COMMENTS*
FIXED BARRIERS OR DAMS				
Sediment Barriers or Dams	At or above upper swash line. Berm crest.	Rapid (hours)	Short – hours/days	Can use on site materials. Can cover with plastic sheets. Easily washed out by waves. Can result in oil-sediment mixture.
Sand bags	At upper swash line. Channels and breaches.	Rapid (hours)	Days/weeks	Labor intensive.
Geotextile or Plastic Barriers	At the base of a dune or dune vegetation, on log lines, in shallow channels, or around man-made structures.	Rapid (hours)	Days/weeks	Can be labor intensive. Ineffective with strong wave action. Can be very effective.
Solid Barriers	Overwash or ephemeral channels.	Slow (days)	Weeks/months	Can be very effective.
MOVEABLE BARRIERS OR BOOMS				
Water-Ballasted Booms	At or above upper swash line.	Rapid (hours)	Days/weeks	Must be drained to move. Labor intensive. Ineffective with strong wave action. Anchors must be removed. Can cause sediment mixing which could result in buried oil.
Conventional Booms	Upper or mid-intertidal zone.	Rapid (hours)	Short – hours/day	Labor intensive. Ineffective with strong wave action. Anchors must be removed.
Sorbent Booms	Upper intertidal zone.	Rapid (hours)	Short – hours/day	Labor intensive. Requires frequent replacement of oiled sorbents. Ineffective with even small wave action. Anchors must be removed.
SUMPS				
Ditches or Trenches	At upper swash line.	Rapid (hours)	Short – hours/day	Easily washed out (filled in), must be carefully located or marked. Can result in buried oil. Ineffective in all but very small wave conditions.

3.5.2 Operational Considerations

TACTIC	*LABOR REQUIREMENTS/SAFETY*	*MONITORING/MAINTENANCE*	*WASTE MANAGEMENT*	*DEMOB ISSUES*
FIXED BARRIERS OR DAMS				
Sediment Barriers or Dams	• Standard equipment operating procedures • Site restriction during construction	• Regular inspection and maintenance recommended	• Impounded oil/oily sand should be recovered regularly • Berm material may be oiled and require removal/treatment (can be considerable)	• Feature must be removed and graded to original topography
Sand Bags	• Labor intensive • OSHA requirements	• Regular inspection and maintenance recommended	• Use local beach sand so clean sand can be returned to beach • Impounded oil/oily sand should be recovered on regularly • Bags and contents may be oiled and require treatment	• Sand bags must be removed and area graded to original topography
Geotextile or Plastic Barriers	• Moderate labor requirements • Smothering hazard • Access restrictions	• Regular inspection and maintenance recommended	• Geotextile and plastic should be segregated for disposal	• Minimal
Solid Barriers	• Moderate labor requirements	• Regular inspection and maintenance recommended	• Barrier materials should be segregated for disposal	• Barriers must be removed and area graded to original topography
MOVEABLE BARRIERS OR BOOMS				
Water-Ballasted Booms	• Low to moderate deployment requirements • Must be drained to relocate	• Regular inspection, maintenance and repositioning may be necessary • Should be removed prior to storm activity	• Minimal – low	• Boom decontamination required • Anchors must be located and removed
Conventional Booms	• Moderate to high labor requirements for deployment (including skirt burial)	• Regular inspection and maintenance • Repositioning and re-anchoring may be necessary • Should be removed prior to significant storm activity	• Minimal – low	• Boom decontamination required • Anchors must be located and removed

TACTIC	*LABOR REQUIREMENTS/SAFETY*	*MONITORING/MAINTENANCE*	*WASTE MANAGEMENT*	*DEMOB ISSUES*
Sorbent Booms	• Low labor requirements for deployment	• Regular inspection, repositioning, re-anchoring • Change out required when sorbents are saturated or water loaded • Locations of sweeps should be precisely marked (e.g. by GPS or stakes) • Should remove prior to storm activity	• Dependent on amount of boom deployed	• Sorbent booms may become buried and difficult to locate and/or removed • Anchors must be located and removed
SUMPS				
Ditches or Trenches	• No trench entry • Restrict access while trenches are open, • Filled trenches may not support personnel or equipment (quicksand)	• Stake or GPS locations • Trenches may fill in and be hard to relocate • Remove collected fluids frequently • Monitor for trapped birds or animals	• Potential for oil burial • Significant oiled material can be generated if oiled trenches are buried	• Buried installations should be inspected for subsurface • Buried oil should be removed or treated in place • Backfill with excavated (clean material) or acceptable substitute • Surface should be returned to original topography

3.6 Shoreline Protection Tactics

This section, along with the Case Studies in Section 4, provides illustrations of the eight generic options for land-based shoreline protection operations.

The following table provides an index of figures for the eight generic protection options.

TACTIC	***ILLUSTRATIONS***	
FIXED BARRIERS AND DAMS		
Sediment Berms, Ridges, Barriers or Dams	3.1A/B/C	4.1A/B 4.2A/B
Sand Bags	3.2A/B/C	4.3A/B/C: 4.5: 4.6
Geotextile or Plastic Barriers	3.3A/B/C	
Solid Barriers	3.4A	4.4: 4.5: 4.6: 4.7A/B/C/D: 4.8
MOVEABLE BARRIERS AND BOOMS		
Water-Ballasted Booms	3.5A/B	4.1C: 4.6
Conventional Booms	3.6A	4.5: 4.6: 4.7B
Sorbent Booms	3.7A/B/C	4.5: 4.7B
SUMPS		
Ditches or trenches	3.8A/B	

Sediment Berms, Ridges, Barriers or Dams

Figure 3.1A *Low (1-m) sand ridge being built by a road grader above the swash line as oil is being washed ashore.*

Figure 3.1B *Barrier created with imported coarse sediment (sand-pebble-cobble) and rubble across a low beach and channel area.*

Figure 3.1C *Sand dams across a shallow ephemeral tidal channel.*

Sand Bags

Figure 3.2A *"Supersacks" placed at the high water level across a low point in a barrier beach where waves can wash over into the backshore on spring tides or during storm surges.*

Figure 3.2B *Armored baskets placed along the highest elevation on a long, low sand barrier.*

Figure 3.2C *Ground view of Figure 3.2B.*

Geotextile or Plastic Barriers

Figure 3.3A *Geotextile barrier across a low section of a barrier beach held in place by imported rubble.*

Figure 3.3B *Plastic sheet barrier to prevent oil being washed into log piles above the intertidal zone (T/V Exxon Valdez response, Alaska).*

Figure 3.3C *Plastic sheet barrier protecting oil from being washed onto an historic property – 16th century Spanish fort and seawall (T/B Morris J. Berman response, Puerto Rico).*

Solid Barriers

Figure 3.4A *Solid sheet pile barrier being constructed across a low channel (see aerial view of channel with completed structure in Figure 4.5). Note oil in the lower half of the image.*

Water-ballasted Boom

Figure 3.5A *Shore-seal boom place across a beach to prevent oil moving along shore. A length of sorbent boom (pink colored "sock boom") is attached to the lower (intertidal) portion of the shore-seal boom (field trials on oiled beaches, Svalbard).*

Figure 3.5B *Water-ballasted anchored as a solid barrier at the high water level. Note the low sand ridge on the landward side of the boom.*

Conventional Boom

Figure 3.6A *Conventional floating boom with skirt buried in the intertidal beach sediments to collect oil moving along shore (field trials, New Jersey).*

Sorbent and Snare Boom

Figure 3.7A *Sorbent (white) and snare boom (colored) booms placed at the high water level to collect oil as it washes ashore.*

Figure 3.7B *Snare and sorbent boom deployed at the swash line.*

Figure 3.7C *Snare boom placed in parallel in the upper intertidal zone to collect oil as it is washed ashore on a rising tide (T/B Morris J. Berman response, Puerto Rico).*

Ditches, Sumps, or Trenches

Figure 3.8A *Trench and sump system in the upper intertidal zone on a wide beach (T/V Amoco Cadiz response, France).*

Figure 3.8B *Trench being dug at the high water line to collect oil as it is being washed ashore on a rising tide (T/V Estrella Pampeana response, Argentina).*

4 Case Examples

Several case examples are taken from the 2010 response to the Deepwater Horizon response along the central Louisiana barrier coast that occurred during late spring and early summer of 2010. During this response there was sufficient time, in some areas, to implement onshore protection strategies involving miles of shoreline to prevent oil from washing across low barriers as well at site specific locations, such as overwash channels and cuts into lagoons and wetlands.

One key element of a successful protection is that diversion, exclusion or containment may require a combination of tactics, as illustrated in Figures 4.5, 4.6 and 4.7B.

4.1 Containment Along Open Beaches

Because of the low elevation and narrow width of many barriers along the sand-starved coast of Central Louisiana, there is a high potential for oil to be transported across the barrier during even moderate storms. To contain this movement of oil onto supratidal berms and possibly into back-barrier environments, large water-ballasted booms were deployed and low sand berms were created with graders and bull-dozers using the existing sediment on the beach (Figure 4.1). The booms were a type of hard shore-seal boom that was anchored to the beach so that they would create a solid barrier and not float. The sand berms were considered ephemeral and were regarded only as short-term solutions.

Figure 4.1A *Bulldozer building a sand berm at the high tidal level.*

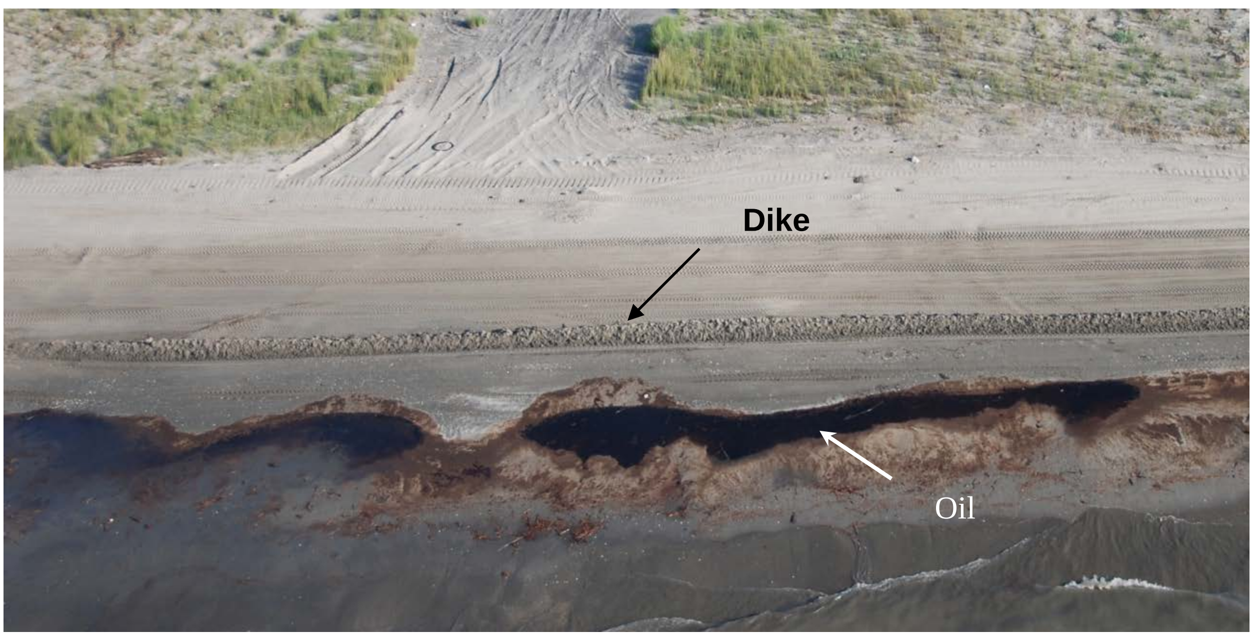


Figure 4.1B *Aerial view of sand ridge with oil being washed ashore.*

Figure 4.1C *Water-ballasted boom that has failed during storm wave activity.*

Dauphin Island, Alabama defines the southwestern border of Mobile Bay and is one of five barriers islands fronting the Mississippi Sound. The island consists of a wide robust eastern segment that contains an 8 to 10 m-high dune system contrasting with a narrow transgressive barrier section that overwashes during major hurricanes and was breached during Hurricane Katrina. This narrower section of the island is less than 3 m in elevation containing a 6-km long residential complex that is susceptible to overwashing. To fend off possible oiling in the residential zone and the transport of oil into the bay, a 2-m high ridge was constructed along the berm crest (Figure 4.2A). A second sand ridge was built further inland on the landward side of the properties parallel to the main road that runs down the middle of the island (Figure 4.2B). The strategy had been used on previous occasions at this location for storm surge protection (Froede 2010).

Figure 4.2A *Sand ridge constructed on Dauphin Island in June 2010. Note that the wave uprush reaches to the toe of the ridge.*

Figure 4.2B *Sand ridges constructed on Dauphin Island in June 2010 landward of the beach properties on higher parts of the beach ridge.*

4.2 Protection of Broad Tidal Flats

In some instances, long expanses of shorelines are susceptible to washovers and possible breaching. Protection structures have to be constructed expediently before storms wash oil across the beach while at the same time having sufficient integrity to withstand breaking waves. The solution at one beach was construction of linked, armored baskets (Figure 4.3A). These baskets consist of flat sections of wire mesh frames lined with fabric that open into a cube, up to 2-m in size, and are filled in place, in this case with coarse riverine sand (Figure 4.3B). The baskets were arranged in a line with two additional bags placed perpendicular to the row (two in front and two behind) at an interval of every 10 baskets (Figures 4.3B and 4.3C). This arrangement provided stability to the structure, but also created a groin-like effect whereby oil and oiled sand collected in these right-angle corners during storms. In other regions, rip-rap revetments were built across the flats (Figure 4.4).

4.3 Barriers Across Overwash or Ephemeral Channels

The tidal breaches along the Central Louisiana barrier coast ranged in width from 50 to 160 m and varied in depth from shallow channels that only convey water at high tide to channels almost a meter deep. A number of different types of construction were used to close off the channels and prevent oil from reaching the back-barrier lagoons and wetlands, including bulkheads built of vertical sheet piling (Figure 4.5), Super Sack bags (Figure 4.6), and rubble and gravel dams (Figure 4.7). Wave-induced sand infilling in front of the structures occurred at all of these sites. The absence of tidal flow through the channels causes deposition within the embayments and an overall straightening of the shoreline (Figure 4.7D). One detriment in this type of protective measure is that the tidal circulation is sharply reduced in the back-barrier lagoon and wetlands.

Figure 4.3A *Armored baskets positioned in front of a tidal flat and bay.*

Figure 4.3B *Close-up of (empty) armored basket arrangement. Note the piles of riverine gravelly sand that were used to fill the bags and provide rigidity and strength.*

Figure 4.3C *Close up view of armored baskets filled with sand.*

Figure 4.4 *Rip-rap revetment protecting a tidal flat and back bay.*

Figure 4.5 *Aerial view of solid sheet pile barrier across a low channel. Note that hard booms, snare booms and Super Sacks were employed prior to bulkhead construction (see Figure 3.4A ground photograph of structure during the construction stage).*

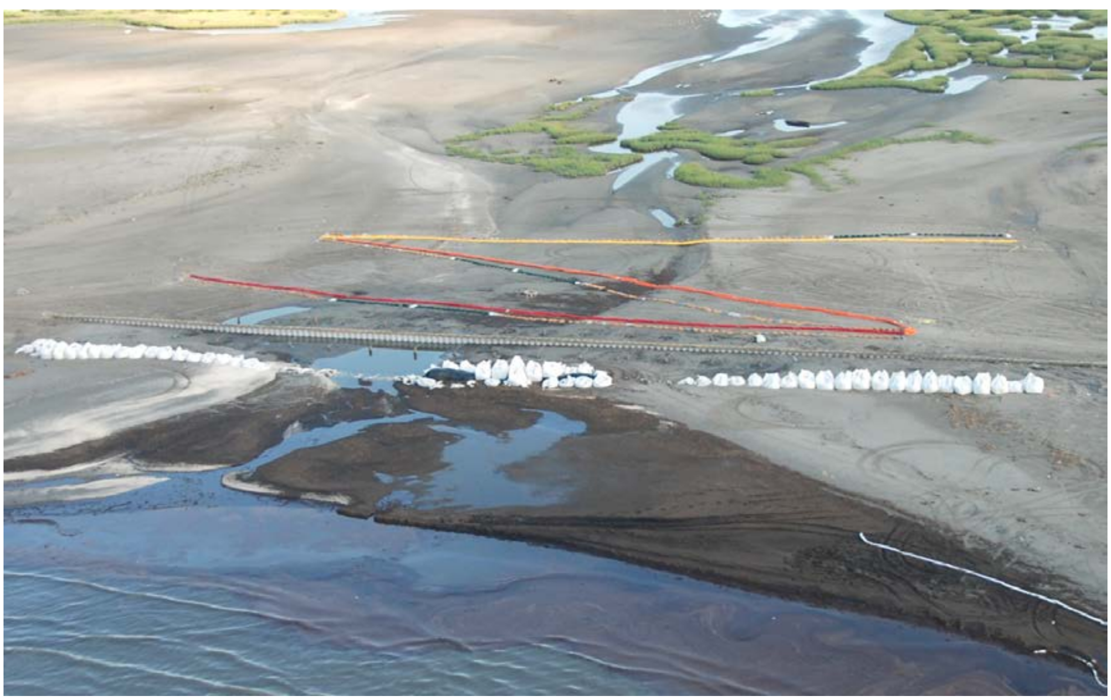


Figure 4.6 *View of channel that was first protected using Super Sacks and water-ballasted booms, then with bulkhead construction. Super sacks were used at several sites as a temporary measure in advance of more permanent solutions such as bulkheads and revetments. The dark material on the ocean side water is a mixture of woody detritus and oil.*

Figure 4.7A *Rubble and gravel dam under construction in a 1-m deep and 160-m wide channel on a low barrier.*

Figure 4.7B *Solid barrier structure (dam) after completion. Subsequent deposition entirely filled the embayment and straightened the shoreline (Figure 4.8).*

Figure 4.7C *Ground photograph of Figure 4.7B taken as the oil came ashore and was prevented from entering the wetlands due to barrier construction.*

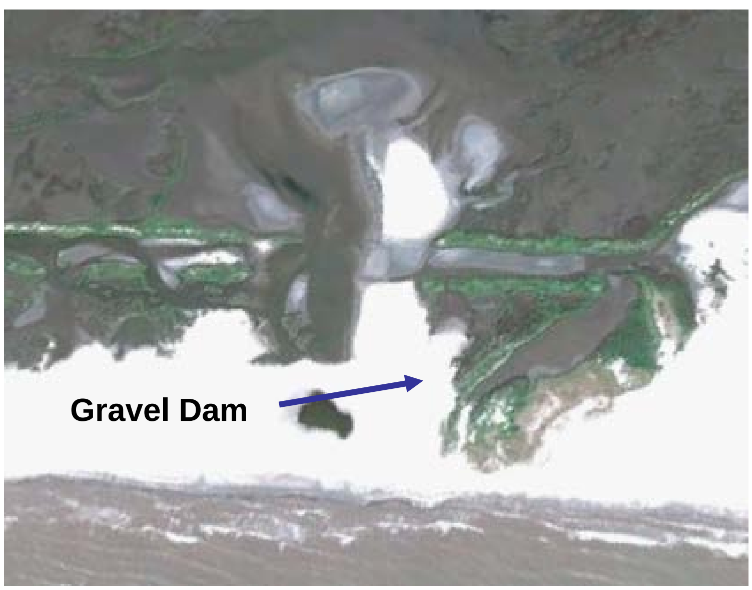


Figure 4.7D *Photograph taken one year after dam was built. Note that the embayment shown in Figure 4.7B has infilled and the shoreline has been straightened.*

T/V *American Trader:* Huntington Beach, California, February 1990.

Earthen berms were constructed across the three channels of the Santa Ana River to prevent oil from entering sensitive wetlands (Figure 4.8). Currents and tidal action in the river had made exclusionary booming ineffective. One 3-m (15-foot) high berm blocked a channel that was approximately 15-m (15 yards) wide. However, downstream runoff resulting from heavy rain washed away all three earthen berms on February 17. The berms were repaired before any oil was carried into the wetlands. The berms proved to be very effective until February 25 when five to ten gallons of oil were washed over the berm into the Huntington Beach wetlands by high tides and surf. Another berm was constructed on the northern channel in late February and this incorporated a gated culvert to allow runoff from the backshore wetlands (Card and Meehan, 1991).

(Photo. J. Michel)

Figure 4.8 *Earthen berm constructed across one of the channels of the Santa Ana River CA following the T/V American Trader spill.*

Lessons Learned – Key Points

- Under normal tide and wave conditions oil can be easily contained along sandy beaches using boom and sediment ridges, but these structures commonly fail under moderate storm events.
- Armored baskets are more robust structures, but can fail during moderate to large storms. Rip-rap revetments and large sediment berms worked best along open sandy beach coasts.
- Breaches and small tidal channels are most effectively barricaded using bulkheads and rock and sediment dams. Super Sacks and hard boom are less robust and fail during storms.
- The small embayments fronting tidal passes and breachways will be filled with sand following barrier construction possibly burying stranded oil.

5 Response Considerations

The planning process that evaluates the potential consequences of a proposed protection strategy typically considers a broad range of issues to help planners and strategists ensure that actions are conducted in a responsible manner to minimize additional impacts to the environment, including human uses.

Consultation with federal, state and local government agencies, as well as with environmental groups and land managers, is a key part of the process to identify potential consequences of proposed actions and strategic alternatives. For example, activities and potential impacts to Threatened and Endangered Species must be consistent with the Federal Endangered Species Act (ESA).

Some proposed actions, such as the construction of a solid barrier across an active or ephemeral channel, may be submitted to the interagency Regional Response Team (RRT) for review and approval.

Construction of shore-zone protective berms and barriers should always be expected to have some effect on the environment and/or shore-zone processes, whether these actions are related to pedestrian traffic, use of machinery, or the physical presence of the berms and barriers. Some effects are likely to be negligible or very short lived (minutes to hours), whereas others have the potential to alter shore zone morphology or processes in a significant manner and have long-term (weeks to months) or permanent effects. In any event, it is fundamental that planning shore zone response actions consider the consequences of any proposed action in terms of their potential short and long term implications, and that monitoring be conducted to verify actual performance. A Net Environmental Benefit (NEB) analysis may be useful in the evaluation of protective actions.

This section briefly identifies some of the issues that should be considered but is not intended as an exhaustive list as each protection strategy is tailored to the local shore-zone character and processes and to the seasonality or other timing associated with habitat and human uses.

a) Sediment Transport

- Construction of berms and barriers may influence sediment transport, both along the shore zone and through channels or inlets. Consultation with, and permission or permitting by, the US Army Corps of Engineers (USCoE) may be required or may be waived during an emergency response.

- Construction of barriers across a channel can lead to sediment deposition and infilling of the seaward portion of the channel to form a straight beach: this can lead to burial of any oil that is washed ashore during that period of deposition.

b) Berm/Barrier Materials

- Local (beach) or imported sediments may be used for berm construction or to fill sand bags.

- If sediments are imported for barrier construction or to fill sand bags these would later be removed if the material is of a different character (type and size) from the local sediments.

- When sourcing local sediments, avoid using already oiled materials.

- Pedestrians and equipment should avoid mixing oiled materials with clean sediments.

- If fill borrow or collection areas (pits and trenches) are located in the shore zone, these areas may collect oil and be buried with sediment: these areas should be clearly marked so that the oiled sediments can be cleaned, treated, relocated and/or restored following a response.

c) Circulation

- Barriers or berms should not interfere with the natural circulation, particularly water exchange between the ocean and tidal lagoons or bays.

- Water exchange issues should be mediated with an underflow system when possible (e.g. a culvert).

- The dam shown in Figure 4.8 was breached by runoff following a rain event and replaced by a culvert dam.

- Dams should be left in place for as short a period as possible (days), until the risk of oiling has passed, to minimize effects of reduced tidal exchange and circulation.

- A dam/causeway was built across Lennox Passage, Chedabucto Bay, Nova Scotia, in 1970 across a tidal channel to protect a complex of sheltered island and bays following the T/V *Arrow* spill; the dam was constructed with 22,000 tons of rock fill in water depths up to 10 m and in currents up to 0.2 m/s (0.4 knots) and a diurnal tidal exchange of up to 40 M m^3; the dam altered the local circulation pattern for several months before removal.

d) Vegetation

- Pedestrians and equipment should avoid vegetation, particularly pro-dune colonizers, dune grasses and wetland plants.

- If access is necessary in a dune area, create access routes with marked pathways and use mats or boards to minimize the area of vegetation disturbance.

- Plan to restore the area after completion of the response activities, this may include reseeding, replanting and/or sediment fence traps.

e) Wildlife and Fish Habitats

- The sensitivity and vulnerability of wildlife typically is highly variable in time and space, and frequently has a distinct seasonality; many wildlife issues are not necessarily covered under the ESA, but should be evaluated in terms of the NEB.

- Federal legislation requires protection of Essential Fish Habitats.

- Many animals and birds usually have defined activity locations or periods, such as feeding and nesting, including alligators and turtles.

- Mammals commonly use the shore zone either for foraging (e.g. raccoons, bears) or as access (e.g. deer).

- Some fish spawn in shore-zone sediment (e.g. capelin) and lagoons/bays.

- Determine existing and near term use of shore zone by wildlife and coordinate protection activities with appropriate agencies and land owners.

f) Human Use

- Current and past human activities include a wide range of recreational, commercial, and industrial uses.

- Many coastal areas are parks, refuges or sanctuaries.
- Land ownership and management issues should be addressed both in terms of activities within the shore zone and access to the coast before implementing any activity.

g) Archaeological and Cultural Resources

- Best Management Practices (BMPs) include consultation with local, state, and federal agencies, and local Native Groups as necessary, to identify the presence of any cultural and archeological resources and to gain consensus for any prioritized protective strategies.

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7 Definitions

beach
a sediment deposit along the shoreline built by waves and wind processes

barrier island or barrier spit
a wave-built accumulation of sediment extending above the *intertidal* zone that runs parallel to the coast and is typically separated from the mainland by a lagoon, bay, and/or wetland: the *backshore of the barrier* often contains active and vegetated dunes.

berm
a relatively flat, sandy platform created by wave and aeolian deposition above the *intertidal zone*: on coarse-sediment beaches there may be several parallel gravel ridges

intertidal zone
the area between the mean low tide water level (LWL) and the mean high tide water level (HWL): this zone is alternately underwater and exposed during each tidal cycle (Figure 7.1)

supertidal zone
the area above the mean HWL that extends to the landward limit of marine processes: this zone is intermittently affected by tidal inundation and wave processes during periods of *spring* high tides or *surges caused by storms or strong onshore winds*

backshore zone
the area landward limit of the *supratidal* zone: this is a terrestrial zone that is only affected by marine processes during periods of exceptional high storm-driven water levels: includes wetlands, lagoons, ponds or rivers

neap and spring tides (astronomical):

- *Neap tides* occur twice during the lunar month when Earth, moon and sun are at right angles during the first and third quarters of the moon, when the tide-generating forces of the sun and moon are subtractive: this condition generates lower than average HWLs and higher than average LWLs and the least range between HWL and LWL

- *Spring tides* occur twice during the lunar month when Earth, moon and sun are aligned during new and full moons, and tide-generating forces of the sun and moon are additive: this condition generates higher than average HWLs and lower than average LWLs and the greatest range between HWL and LWL

wind or storm surges (meteorological)
a rise in the water level along the shore generated by strong onshore winds and/or low atmospheric pressures: frequently wind-driven waves are superimposed on the surge to further elevate water levels

overwash or washover

overwash is the landward transport of sediment into the *supratidal* or *backshore* zones during periods of elevated tides or storms: sediments (and oil) may be transported across a *barrier beach* into a wetland, pond or lagoon (Figure 7.2)

trafficability

the bearing capacity of beach sediments affects the ability for pedestrians and vehicles to travel across a section of beach and the speed at which vehicles can operate: the bearing capacity varies alongshore and across shore depending on sediment size, wetness and slope

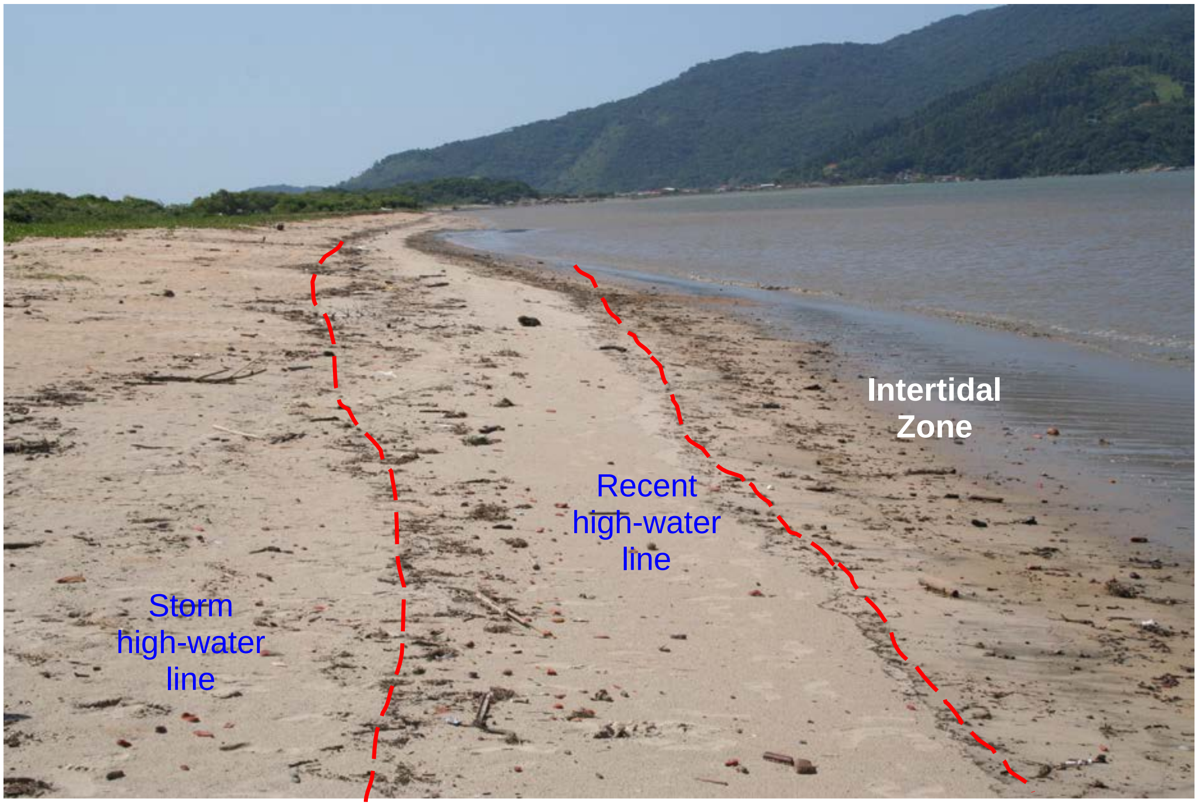

Figure 7.1 *Sand beach with well-defined different high-water levels.*

Figure 7.2 *An overwash channel cut through the beach and dune system along a sandy barrier, creating a small washover fan on the back barrier lagoon shore.*

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