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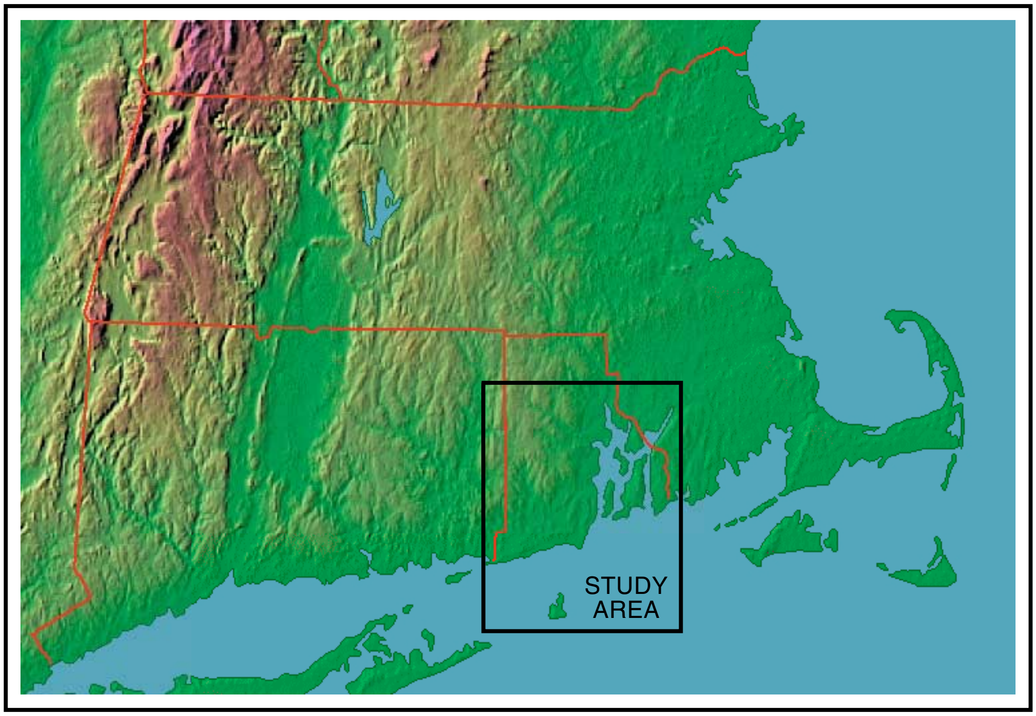
Tidal Inlet Protection Strategies for Oil-Spill Response

Coast of Rhode Island



BASED ON RESEARCH SUPPORTED BY

Rhode Island Department of Environmental Management

Tidal Inlet Protection Strategies for Oil-Spill Response

Coast of Rhode Island

Based on research supported by
Rhode Island Department of Environmental Protection

May 1999

Prepared by Miles O. Hayes and Linos Cotsapas, Research Planning, Inc.

Front Cover Image Courtesy of Ray Sterner; Johns Hopkins University, Applied Physics Laboratory

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At Research Planning, Inc. (RPI), Joe Holmes assisted with data collection and produced the graphics for the report and Dot Zaino did the final word processing and assisted in report production.

INTRODUCTION

The coastal inlets of Rhode Island are the focal points for designing strategies to protect the vital resources of the state's coastal ponds and bays, marshes, and tidal flats because it is through these conduits that oil spilled on open ocean waters could reach the resources. Therefore, this project was commissioned by the Rhode Island Department of Environmental Management (RIDEM) to develop potential protection strategies for each significant inlet occurring along the coastline of the state (Table 1; Fig. 1). The discussion of each inlet included in this report alludes to the range of conditions that might occur at the inlet; however, the proposed protection strategies are based on our best professional judgment of what would work under average wave and tide conditions. The diagrams that accompany the proposed protection strategies are schematic representations of boom placement, collection points, anchor points, and skimmer locations. The symbols used to depict booms are not shown to true scale. The actual length of boom segments will be determined by local conditions at the time of the spill. The proposed strategies should not be interpreted as the only workable protection scheme. Each spill will be time, place, and circumstance specific. Therefore, the strategy finally used to protect the inlet will have to be chosen at the time of the spill. A total of 53 inlets, located on Figure 1 and listed in Table 1, are treated in this report.

The field study of the inlets on the Rhode Island coast was carried out between 17 and 25 March 1999. On 17 March, Hayes and Cotsapas of RPI conducted an overflight of all but six of the inlets at low spring tide and numerous oblique color aerial photographs were taken at each inlet from altitudes of 800 to 1,500 feet. Five of the inlets not covered in the overflight were too near the Providence airport for safe flying with a small plane, and the one inlet on Block Island (Great Salt Pond) was also not covered for safety purposes. These photographs are supplemented by low-tide vertical aerial photographs that had been purchased earlier from the U.S. Geological Survey (USGS) (EROS–NAPP; flown in March, 1995).

Except for two inlets (Providence Harbor and Sakonnet River; The Cove), the proposed protection strategies emphasize flood-tidal conditions only, because the basic assumption is that the strategy be designed to deal with spilled oil coming to the inlet from the open ocean. These proposed potential strategies are based on the information at hand on waves and tidal currents. Where such data are missing,

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TABLE 1. Inlets for which protection strategies were developed.

INLET NUMBER/ NAME	INLET CLASS*	GEOMORPHIC CLASS**	INLET NUMBER/ NAME	INLET CLASS*	GEOMORPHIC CLASS**
1. Great Salt Pond	B	1	21. Bissel Cove; Annaquatucket R.	C	2
2. Winnapaug Pond; Weekapaug Breachway	B	1	22. Duck Cove	C	2
3. Quonochontaug Pond	B/C	1	23. Wickford Harbor	B	6
4. Ninigret Pond; Charlestown Breachway	B	1	24. Allen Harbor	C	6
5. Trustom Pond	D	3	25. Tibbets Creek	D	5
6. Card Ponds	D	3	26. Potowomut River	C	7
7. Pt. Judith Pond and Harbor	A	1	27. Old Mill Creek	C/D	2
8. The Narrows (Pettaquamscutt River)	B	2	28. Occupessatuxet Cove	C	7
9. Long Pond	D	4	29. Passeonkquis Cove	C	7
10. Briggs Marsh	C/D	4	30. Pawtuxet Cove	C	6
11. Little Pond Cove	D	4	31. Providence Harbor	A	6
12. Tunipus Pond	D	4	32. Bullock Cove	C	6
13. Quicksand Pond	C/D	4	33. Drown Cove	C/D	2
14. Mackerel Cove	C	7	34. South of Annawomscutt Creek	D	5
15. Dutch Island Harbor–Fox Hill Pond	C	2	35. Mussachuck Creek	D	5
16. Dutch Island Harbor–Sheffield Cove	C	7	36. Warren River	A/B	7
17. Dutch Island Harbor–Great Creek	C	7	37. Mill Gut	B/C	2
18. Dutch Island Harbor–Jamestown Brook	D	2	38. Sheep Pen; Coggeshall Coves	C	7
19. Wesquage Pond	D	4	39. Nag Pond	C/D	5
20. Greene Point	D	5	40. Jenny Pond	D	5

TABLE 1 CONT. >> VIEW INDEX MAP >>

VIEW TABLE 1 >>

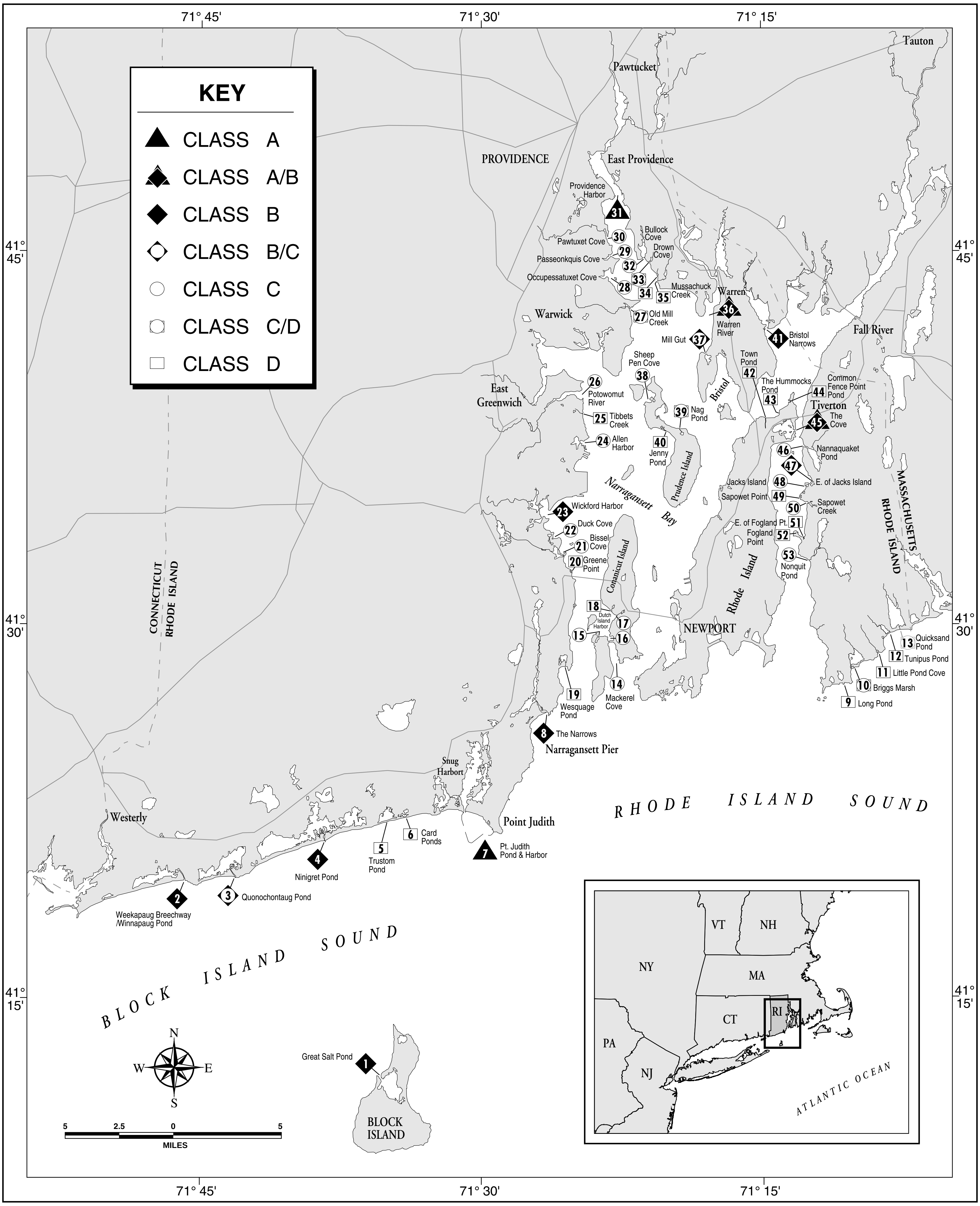

FIGURE 1. Coastal inlets for which protection strategies have been devised.

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TABLE 1. Continued.

INLET NUMBER/ NAME	INLET CLASS*	GEOMORPHIC CLASS**	INLET NUMBER/ NAME	INLET CLASS*	GEOMORPHIC CLASS**
41. Bristol Narrows	B	7	48. Jacks Island	C	5
42. Town Pond	D	5	49. Sapowet Point	D	5
43. Pond West of The Hummocks	D	5	50. Sapowet Creek	B/C	2
44. Pond at Common Fence Point	D	5	51. East of Fogland Point	D	4
45. Sakonnet River; The Cove	A/B	6	52. Fogland Point Pond	D	5
46. Nannaquaket Pond	C	7	53. Nonquit Pond	C	1
47. East of Jacks Island	B/C	4			

* See Table 2 for Inlet Class scale.

** See discussion of Geomorphic Class (pages 17-20).

1- Classic Tidal Inlets
2- "Half Inlets"
3- Natural Temporary Washover Channels into Coastal Ponds
4- Small Permanent Channels Through Bayhead Pocket Beaches that Shelter Coastal Ponds
5- Minor Headland or Depositional Bar Systems With Channels to Pond/Marsh
6- Harbors
7- River Mouth Entrances and Natural Coves

inferences based on the geomorphology were used. It would be helpful if site-specific current studies were carried out in some of the more difficult inlets in order to fine-tune the proposed strategies.

The following elements are included in the discussion of most of the individual inlets:

- Inlet summary sheet, which includes Inlet Class (based on degree of difficulty of protection), brief summaries of principal resources at risk, potential protection strategies, geomorphology, resources required, and other comments as necessary.

- Color reproduction of USGS topographic maps (1:24,000) showing inlet location.

- Vertical aerial photograph of the inlet, as well as at least one supplementary oblique color aerial photograph and a ground photograph (where available) of one of the most critical collection points.

- Field sketch of inlet (in plan view) with relevant morphological/ sedimentological information, upon which a potential protection strategy (for flood conditions) is printed in color. Protection strategies for ebb conditions are given for two inlets.

- Collection point summary table, which includes a brief discussion of the collection points and possible staging areas plus comments concerning the type of equipment to be used at each collection site.

INLET PROTECTION STRATEGIES USED

In making a decision on a protection strategy, the following hierarchy of controls dictated the final strategy:

1) Physical processes of the inlet
2) Protection priorities
3) Effectiveness of response

If the waves were assumed to be too large or tidal currents too strong for booms to function in certain parts of the inlet, the strategy called for fall back to more protected sites. Information from a number of sources dictated which parts of the pond/bay system landward of the inlet required priority protection. Typically, most of the ponds and bays contain sensitive salt marshes and tidal flats, as well as significant bird populations. The potential effectiveness of response was also given careful consideration. The probable effectiveness of a response would be controlled by such factors as access, particularly to collection points, types of equipment required, and logistics support required.

Several additional assumptions that affected the final decision on a particular protection strategy include:

- When oil is on the water, the first priority is containment and the second is recovery.
- Following guidelines established by the U.S. Coast Guard Strike Team, we conclude that deflection booms are the best means of controlling oil in the vicinity of tidal inlets because of the common occurrence of tidal currents greater than 0.7 knots, the threshold velocity for entrainment of oil past a boom set at 90° to the current (see diagram in Figure 2).
- The preferred method of recovery is to divert oil to a collection point along shore where the oil can be collected from the water surface. Trapping oil against vertical pilings, concrete seawalls, or protection boom is desirable. It is also possible to use as collection points fine- to medium-grained sand beaches, which are easily cleaned and penetration of oil into the sediment is minimal. Coarse-grained sand, shell and gravel beaches, riprap, tidal flats, and marshes should not be used as collection points except as a last resort. Where workable collection points are not available on land, open water skimmers are recommended.

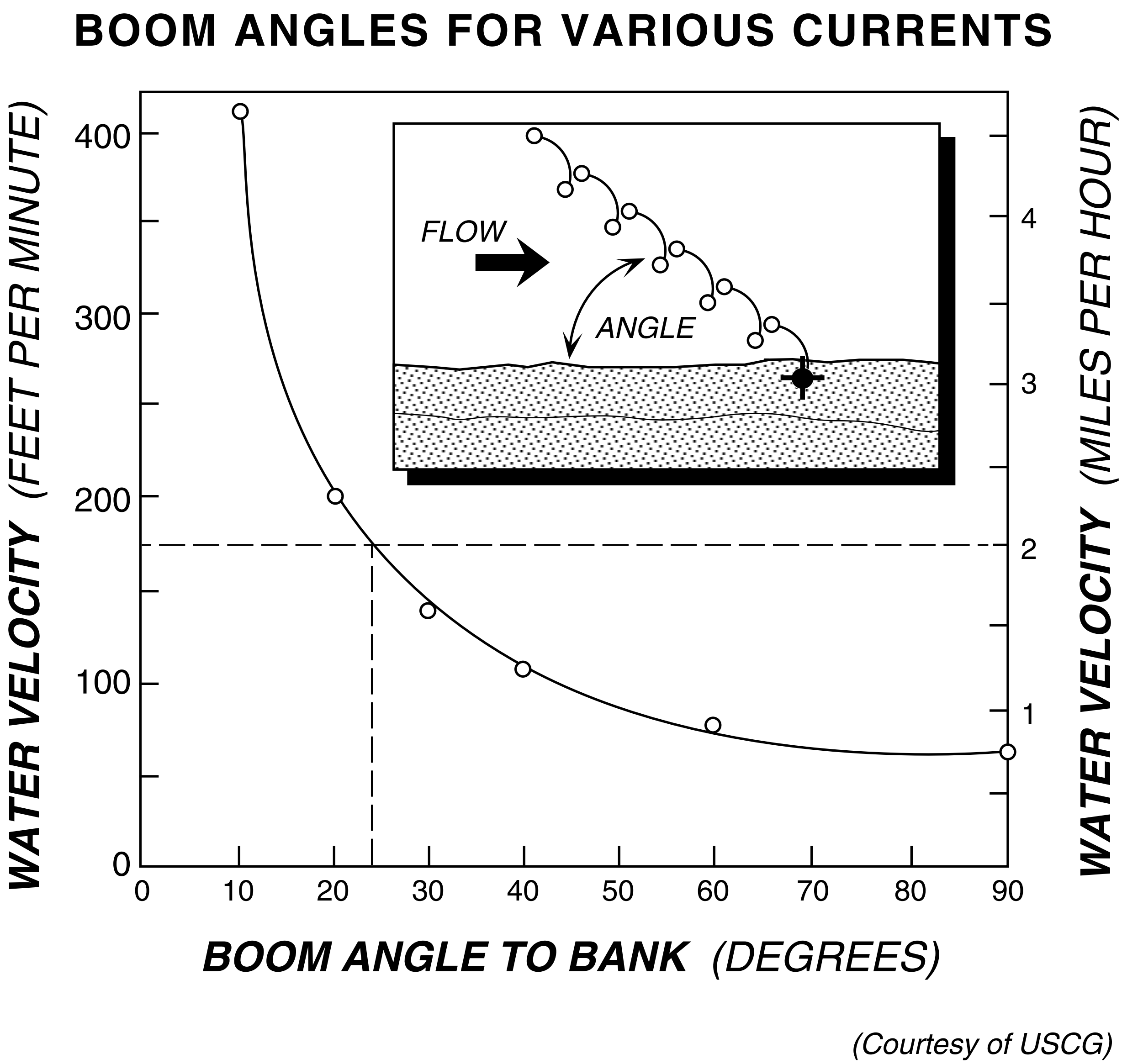

FIGURE 2. Angles to set booms to avoid entrainment of the oil based on water current velocity in miles per hour (courtesy of U.S. Coast Guard Strike Team).

- Entrainment of the deflection booms will occur, unless they are set at very small angles to the current, if the current velocity exceeds about 3.5 knots. Large waves also may cause both entrainment and splashover, depending upon the physical configuration of the boom.

- The protection strategies depicted relate only to spills located seaward of the inlet, and the strategy recommended applies only to flood-tide conditions (except for the strategies proposed for Providence Harbor and Sakonnet River; The Cove, which also include ebb-tide conditions).

An example of how one of the protection strategies is presented graphically is given in Figure 3. In that example, Point Judith Pond (inlet no. 7; Fig. 1), it was assumed that it would be necessary to fall back inside the inlet for the first line of defense, because of anticipated flood currents of up to three (3) knots between the jetties and the potential for wave action in the entrance during stormy conditions. Two sites were chosen as the primary collection points (first line of defense) on land (labeled CP-1 and CP-5 on Fig. 3) for oil coming through the inlet throat. Site 1 is a small pocket beach area located on the western shoreline of the inlet directly facing the inlet throat, and site 5 is a seawall located a bit further landward along the harbor shoreline to the east of the inlet channel (Fig. 3). The primary collection points have contingency back-up deflection boom and collection points, should entrainment occur at the first line of defense. All but one of the collection points is land based, with one skimmer being proposed as a backup collection point positioned to the northeast of the large mid-channel shoal located about two thousand feet north of the landward end of the jetties. The red arrows on Figure 3 indicate the probable path of surface oil during the flood tide. Some of the critical recommended anchor points for the boom are also shown. THE SYMBOLS USED TO DEPICT BOOMS ARE NOT SHOWN TO TRUE SCALE. The length of the segments of boom to be used will be determined by local conditions.

INLET SKETCH MAP

Inlet Name: POINT JUDITH POND AND HARBOR

Inlet Number: 7

Recorder(s): MOH/LC/SM

Date/Time: 18 MARCH 1999; 1500

Tide Stage: LOW

Inlet Classification: A

CHECKLIST

- ✓ North Arrow
- ✓ Scale
- ✓ Substrate Type

LEGEND

- Red Channel Marker Buoy
- Green Channel Marker Buoy
- Marsh
- Riprap
- Sand
- Sand & Gravel
- Gravel

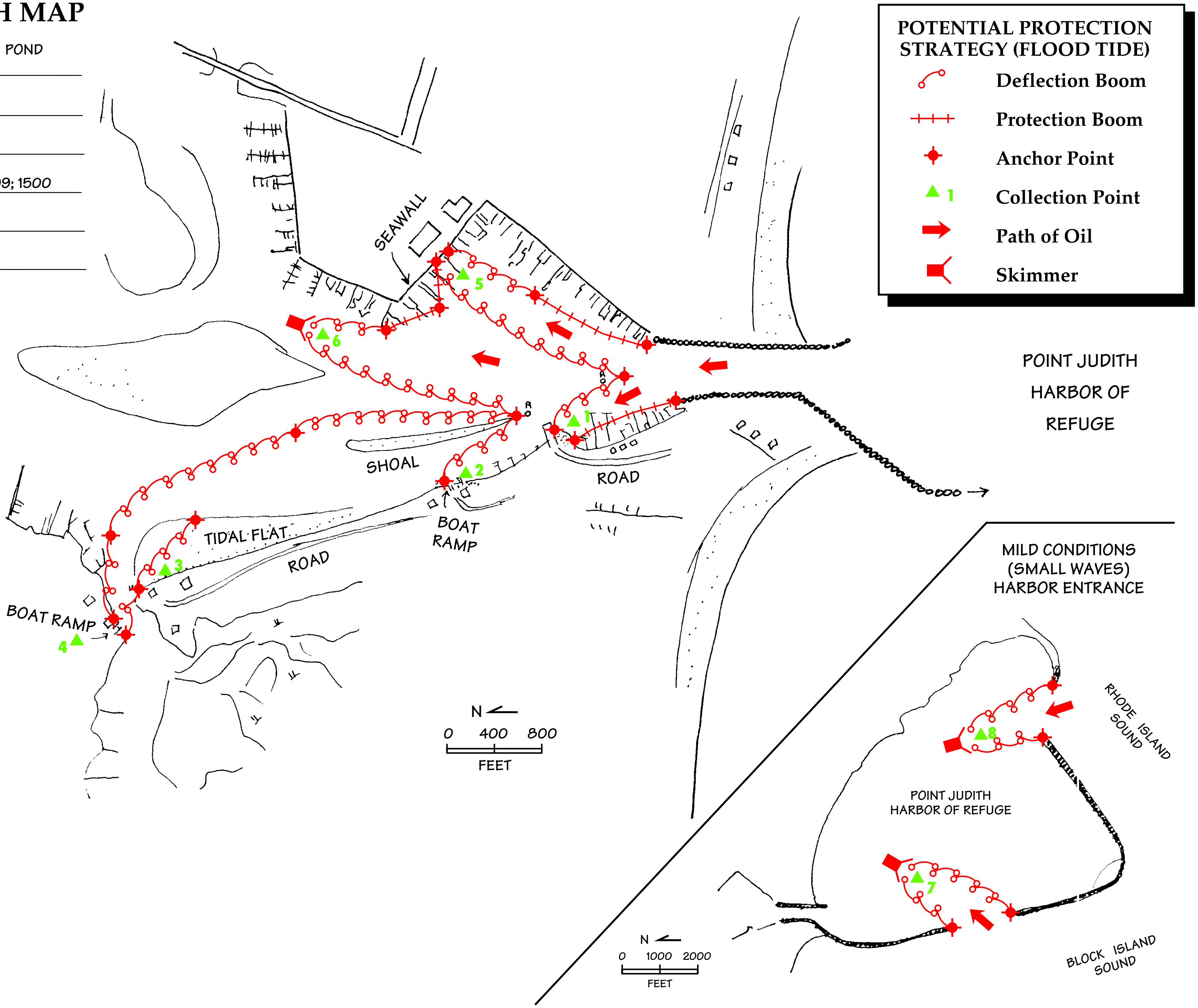

FIGURE 3. Inlet sketch map of Point Judith Pond and Harbor of Refuge.

INLET CLASSIFICATION

In the field, the inlets on the coast of Rhode Island were classified on the basis of the degree of difficulty for containment and recovery of spilled oil once it reaches the inlet. This ranking, or "Inlet Class," which is summarized in Table 2, is on a scale that ranges from A to D, with the inlets classed as A's being the most difficult, and, consequently, the most expensive ones to deal with. The occurrence of the different inlets, by class, is illustrated in Figure 1. In Rhode Island, two inlets were classified as A, Point Judith Pond and Harbor and Providence Harbor. Two inlets, Warren River and Sakonnet River; The Cove, were classified A/B, because it was thought that changing hydrodynamic conditions (e.g., large waves, high spring tides) would significantly increase the difficulty of protecting the inlets (changing the ranking from class B to class A). Six inlets were ranked B, four B/C, 16 C, five C/D, and 18 D.

TABLE 2. Proposed ranking scale for the coastal inlets of Rhode Island, based on estimated degree of difficulty for containment and recovery of spilled oil.

A. Extremely difficult because of large size and extreme physical conditions. Large expense because of magnitude of resources to protect.

B. Difficult because it is subject to strong currents and/or large waves.

C. Less difficult because of smaller tidal prism and relatively weak tidal currents.

D. Can be closed with sediment dike under normal adverse conditions.

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TIDAL INLETS—GENERAL

Origin

In the classic sense, tidal inlets are channels that divide barrier islands into segments. They are subject to reversing tidal currents, and are conduits for the volume of water that flows in and out of the bay/estuarine system landward of the inlet during a tidal cycle, called the tidal prism. Tidal inlets on the sandy coastal plains of the eastern USA are usually formed by either of two mechanisms: (1) storm-generated scour channels (resulting inlets are usually shallow and prone to rapid migration); and (2) closure of estuarine entrances by growth of sand spits (resulting inlets usually deep and fixed in place).

Morphology

As shown in Figure 4, a typical tidal inlet in a barrier island setting consists of a deep channel between the adjacent sand spits, called the inlet throat, and lobate-shaped sand bodies on either side of the inlet, called tidal deltas. The sand deposit on the landward side of the inlet, the flood-tidal delta, is typically composed of sheet-like lobes of sand with seaward-sloping ramps on their seaward sides covered by landward migrating waves of sand. The flood-tidal delta at The Narrows (Pettaquamscutt River; no. 8, Fig. 1) is illustrated by the oblique aerial photograph in Figure 5A. Note the landward oriented waves of sand on the top of the sand shoal, which indicates that the flood current is the dominant current crossing the shoal. In some places, the flood-tidal delta is a very complex array of channels, sand flats and salt marshes (see discussion of Ninigret Pond; no. 4; Fig. 1). The sand deposit on the seaward side of the inlet, the ebb-tidal delta, is built seaward by ebb-tidal currents, but waves mold the outer margins into an arcuate shape and build landward migrating intertidal bars (swash bars) on the delta surface. The tidal flow on the ebb-tidal delta is horizontally segregated, with the main ebb channel, which usually projects perpendicular to shore off the inlet throat, being dominated by ebb-tidal currents. Shallower, flood-dominant channels (marginal flood channels) flank both sides of the ebb-tidal delta (see Figure 4). The marginal flood channels are important in oil-spill response because the first waters to enter the inlet during the rising tide flow down these channels, even as residual ebb-tidal currents are flowing out the main ebb channel. This allows for a period of time (one hour or so) when any oil headinglandward would be moving only down the marginal

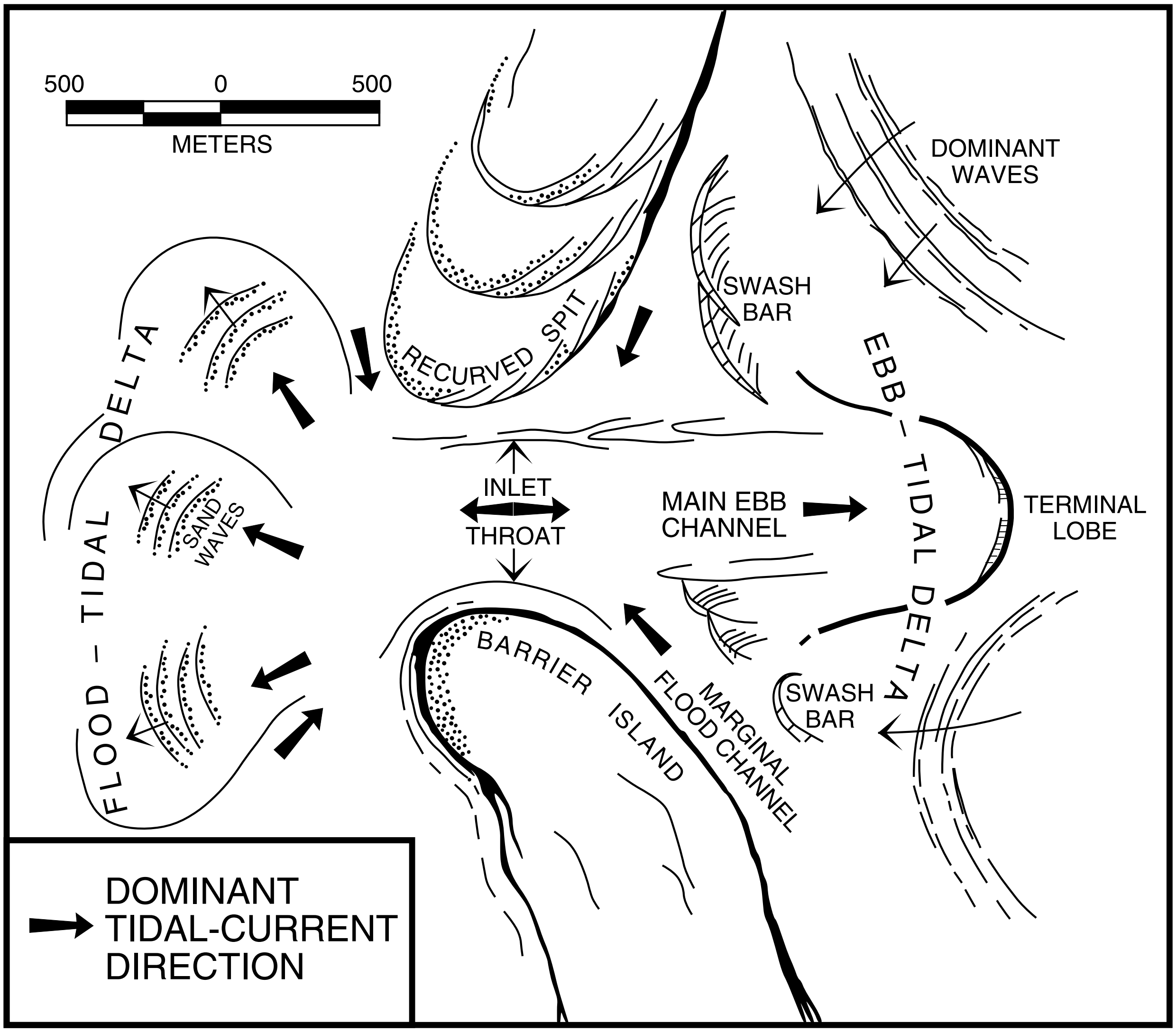

FIGURE 4. General model showing the morphological components of a typical tidal inlet.

flood channels, during which time it could possibly be diverted to the adjacent beach, rather than allowing it to enter the inlet and the highly sensitive pond/bay behind it. The ebb-tidal delta at Sapowet Creek (no. 50; Fig. 1) is illustrated by the photograph in Figure 5B.

Very few inlets in nature have tidal deltas of equal size as is depicted in Figure 4. Most inlets, including those in Rhode Island, are either flood dominated or ebb-dominated. Flood dominated systems are most common where the bay/ pond complex landward of the inlet is open water. In this instance, the flood-tidal delta is usually much larger than the ebb-tidal delta. On the other hand, if the area

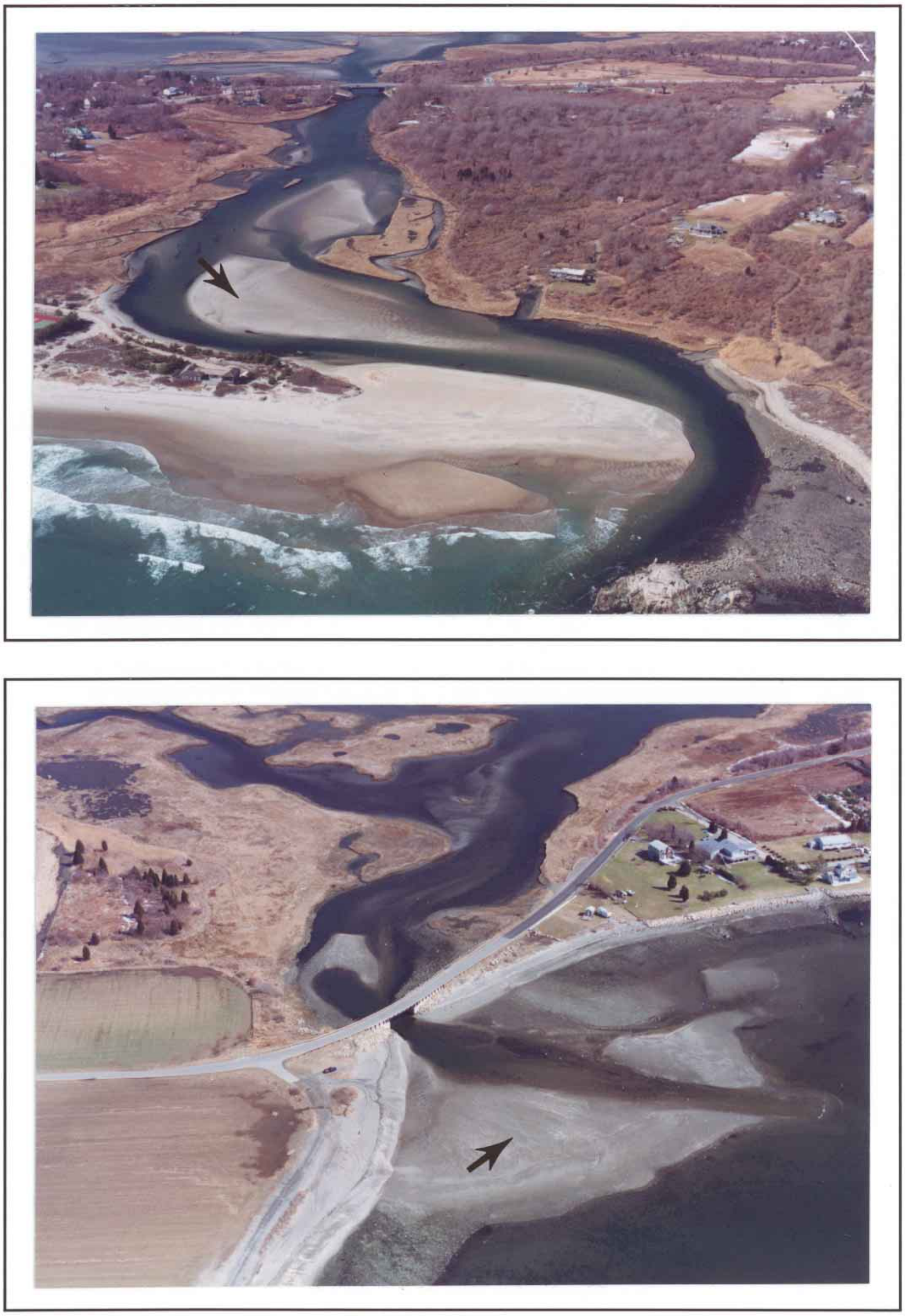

FIGURE 5. Rhode Island tidal deltas. Compare with diagram in Figure 4. Photographs taken at low tide on 17 March 1999.

A. Flood-tidal delta (arrow) at The Narrows (Pettaquamscutt River).

B. Ebb-tidal delta (arrow) at Sapowet Creek.

landward of the inlet is a complex system of sinuous tidal channels, tidal flats, and salt marshes, the inlet tends to be ebb-dominated and the ebb-tidal delta is much larger than the flood-tidal delta. The inlet shown in Figure 5B, Sapowet Creek, is an excellent example of an ebb-dominated inlet.

TIDAL INLETS— COAST OF RHODE ISLAND

Introduction

Tidal inlets in Rhode Island are highly variable. Only six of the 53 inlets discussed in this report conform to the morphological pattern described in Figure 4, which is based on the typical tidal inlets found along barrier islands of the Southeast and Gulf Coast shorelines of the USA. Examples include Point Judith Pond (Figure 3) and Nonquit Pond (no. 53; Fig. 1). However, Rhode Island's coast is an indented, rocky coast that was intensely glaciated during the ice ages. Major barrier islands, per se, are uncommon along this shoreline, and there are many rocky headlands and intervening valleys flooded by sea water during the most recent sea level rise, creating a very irregular and complex shoreline. Consequently, a variety of shoreline indentations that receive ocean flow through relatively narrow constrictions and contain sensitive coastal resources, such as marshes and tidal flats, occur along the coast. These indentations have been treated as "tidal inlets" in this project. The different types of "inlets" or "Geomorphic Classes" include: (a) classic tidal inlets; (b) "half inlets;" (c) natural temporary washover channels into coastal ponds; (d) small permanent channels through bayhead pocket beaches that shelter coastal ponds; (e) minor headland or depositional bar systems with channels to pond/marsh; (f) harbors; and (g) river mouth entrances/natural coves.

Classic Tidal Inlets

Six of the inlets surveyed are in this category. One is the single tidal inlet on Block Island, the entrance to Great Salt Pond, which is stabilized by jetties, as it serves as a significant navigational channel. The small inlet into Nonquit Pond (no. 53; Fig. 1), located on the east shore of the Sakonnet River, is the lone completely natural inlet in this group. It has no jetties and is ebb-dominated. The other four inlets are located on the outer, southwest coast of the state. These four inlets were summarized in an excellent paper by Boothroyd, et al. (1985), who had the following comments (p. 36-39):

> "The Rhode Island coast is microtidal (<2m mean tidal range) .... , has low to moderate wave energy impacting on the spits (mean wave height: 80 cm) .... The natural tidal inlets through the barrier spits are narrow and shallow (less than 1m deep), and close intermittently because longshore transport of sand tends to seal the inlet throats. Discharges of the small tidal prisms ... into and out of the lagoons are not large enough to keep

> the inlets open. But all of the larger lagoons now have inlets (called breachways in local terminology) stabilized by jetties constructed in the 1950's and 60's; Point Judith Pond ... was permanently opened in 1909 .... The stabilized inlets are wider and deeper than were the natural inlets. The largest is Point Judith breachway .... now 75m wide and up to 9 m deep, which serves the fishing port of Galilee."

With respect to oil-spill response, man-modified inlets are typically easier to deal with than natural systems (of the same size), because of the ease of access to land-based collection points. On the down side, narrowly constricted jetties normally accentuate tidal currents a great deal, which usually necessitates operating landward of the jetties to collect oil. According to Boothroyd (pers. com.), maximum flood currents usually average around three knots in the "breachways" of the southwest coast, but the currents decrease rapidly landward of the jetties.

"Half Inlets"

The irregular outline of the shoreline caused by valleys carved during lowered sea level, indentations caused by glacial processes such as ice-block basins, and so forth, has been straightened over time by barrier spits built across these indentations, or embayments. This has only occurred in areas where sediment is available and waves are large enough to generate longshore sediment transport. If the longshore transport is strong, a single spit will build most the way across the entrance so that the entrance channel abuts an adjacent upland, which is commonly underlain by bedrock. This process results in a "half inlet" configuration. A good example of this type of inlet is illustrated in Figure 5B (Sapowet Creek). Compare Figure 5B with the model in Figure 4.

A total of nine of the inlets surveyed are in this group. They show a wide range in degree of difficulty, depending mainly upon their size. There is one B (The Narrows; no. 8, Fig. 1), two B/Cs, three Cs, two C/Ds, and one D. The degree of difficulty was increased at Mill Gut (no. 37; Fig. 1) by bridge construction, which created a narrow constriction to tidal flow and, hence, stronger tidal currents in the inlet throat.

Natural Temporary Washover Channels Into Coastal Ponds

Two temporary channels of this type, at Trustom Pond and Card Ponds (nos. 5 and 6; Fig. 1), are present on the southwest shoreline. Both of these channels are opened artificially on occasion, once a year at Trustom Pond and about six to ten times a year at Card Ponds (C. Hebert, pers. com.). Although they are fairly wide, around 100-150 yards, they could be closed in the event of their being open during an oil spill, because of the high elevation of the washover channels and the abundance of sediment available for dike construction. Thus, both of these inlets are class D.

Small Permanent Channels Through Bayhead Pocket Beaches that Shelter Coastal Ponds

These features are similar to the previous group except that they have permanent channels, presumably because of larger tidal prisms. Typically, the small channel has a fairly large flood-tidal delta associated with it. These flood-tidal deltas are no doubt augmented by storm washover processes. All but one of the eight inlets in this group were either class D or C/D, because of the relatively small tidal prisms and the abundance of sediment available for dike construction. The inlet east of Jacks Island (no. 47; Fig. 1) was classed B/C, because of the fairly large marsh/ tidal flat complex behind the outer shore and the low, washed over nature of the sediment-starved, wide spit complex across the entrance.

Minor Headland or Depositional Bar Systems With Channels to Pond/Marsh

This was the most common of the inlet types surveyed, a total of 12. Because of the extremely irregular nature of the shoreline, it is common to find local beach ridge complexes sheltering small ponds with marshes and tidal flats. These features usually form in one of two methods: (1) minor headlands (or forelands) where wave refraction patterns converge to build triangular spit forms out into the water that shelter the pond/marsh; or (2) slight indentations in the shoreline which have spits built across them, again sheltering the pond/marsh. The beach ridge/ spit systems are usually composed of mixed sand and gravel. Some have beach berms of pure shell (limpets and mussels). Ten of the 12 inlets in this category were class D. Any inlet with a higher ranking (C or C/D) had a sparse sediment supply for constructing a sediment dike.

Harbors

Six of the areas surveyed were classified as harbors. These were either manmade harbors or highly modified natural harbors. Of these, one was class A (Providence Harbor), one class A/B (Sakonnet River; The Cove; no. 45, Fig. 1), one class B (Wickford Harbor; no. 23, Fig. 1), and three class C. Very strong flood currents occur at the southern entrance to the Sakonnet River; The Cove harbor as a result of an old roadway constricting flow.

River Mouth Entrances and Natural Coves

A total of ten inlets were either river mouth entrances or natural coves that were flooded with marine water during the last sea level rise. None of these entrances contain major barrier spits, thus they tend to be relatively deep at the entrance, and, as a rule, currents are not as strong as in some of the other types of inlets. Because of this morphology, eight of these inlets were class C. An exception to this generalization occurs at Bristol Narrows (no. 41; Fig. 1), where strong flood currents result from natural constriction of the entrance by bedrock. Therefore, Bristol Narrows was ranked B. Because of its complexity, large size, and abundance of resources, we classified the Warren River (no. 36; Fig. 1) as A/B.

Tidal Current Data

Meaningful tidal current information on the tidal inlets of Rhode Island is relatively scarce. Information in available tidal current tables describe the currents in many of the inlets as "variable and weak." Our field observations documented currents of 3-5 knots during peak flood in a few localities. Jon Boothroyd (pers. com.) informed us that the jettied inlets along the southwest coast have peak flood currents of around 3 knots between the jetties. We believe our protection strategies are conservative enough to accommodate the stronger currents where they occur, by either: (a) falling back inside the inlet to where the currents are weaker; (b) aligning booms at low angles and proper lengths; or (c) providing sufficient backup protection.

BOOM REQUIREMENTS

Approximate measurements of the footages of boom required for the strategies designed for the Rhode Island inlets are given in Table 3. The totals include all of the back-up boom configurations shown on the strategy diagram. Deflection boom is boom segments set up at an angle to the current flow, cascade style, so as to divert the oil to a collection point down current. Protection boom is established around areas designated for protection, such as salt marshes and marina entrances.

TABLE 3. Approximate footages of boom required for the potential protection strategies presented for the Rhode Island coast. Refer to Figure 1 for site names and locations.

		FEET OF BOOM	
INLET NAME	**CLASSIFICATION**	**DEFLECTION**	**PROTECTION**
Great Salt Pond	B	9,600	--
Winnapaug; Weekapaug Pond	B	2,100	1,900
Quonochontaug Pond	B/C	2,900	--
Ninigret Pond	B	1,400	--
Trustom Pond	D	*	*
Card Ponds	D	*	*
Point Judith Pond and Harbor	A	21,900	3,100
The Narrows (Pettaquamscutt R.)	B	3,900	2,400
Long Pond	D	*	*
Briggs Marsh	C/D	--	2,800
Little Pond Cove	D	*	*
Tunipus Pond	D	*	*
Quicksand Pond	C/D	1,000	3,200
Mackerel Cove	C	3,800	--
Dutch Island Harbor–Fox Hill Pond	C	700	2,600
Dutch Island Harbor–Sheffield Cove	C	--	1,800
Dutch Island Harbor–Great Creek	C	2,700	2,100
Dutch Island Harbor–Jamestown Brook	D	*	*
Wesquage Pond	D	*	*
Greene Point	D	*	*

TABLE 3. Continued.

INLET NAME	CLASSIFICATION	FEET OF BOOM	
		DEFLECTION	PROTECTION
Bissel Cove; Annaquatucket River	C	1,750	400
Duck Cove	C	600	--
Wickford Harbor	B	6,900	1,500
Allen Harbor	C	800	100
Tibbets Creek	D	*	*
Potowomut River	C	4,500	500
Old Mill Creek	C/D	--	1,900
Occupessatuxet Cove	C	4,700	1,700
Passeonkquis Cove	C	1,300	400
Pawtuxet Cove	C	2,700	900
Providence Harbor	A	12,000**	3,900**
Bullock Cove	C	1,750	100
Drown Cove	C/D	600	300
South of Annawomscutt Creek	D	*	*
Mussachuck Creek	D	*	*
Warren River (and upstream)	A/B	9,100	8,400
Mill Gut	B/C	600	700
Sheep Pen/Coggeshall Coves	C	--	4,100
Nag Pond	C/D	--	2,200
Jenny Pond	D	*	*
Bristol Narrows	B	5,800	500
Town Pond	D	*	*
Pond West of The Hummocks	D	*	*
Pond at Common Fence Point	D	*	*
Sakonnet River; The Cove	A/B	4,050***	100***
Nannaquaket Pond	C	1,250	--
East of Jacks Island (Sapowet Cove)	B/C	--	2,400
Jacks Island	C	900	1,500
Sapowet Point	D	*	* & 1,200
Sapowet Creek	B/C	2,450	1,200

TABLE 3. Continued.

INLET NAME	CLASSIFICATION	FEET OF BOOM DEFLECTION	FEET OF BOOM PROTECTION
East of Fogland Point	D	*	* *
Fogland Point Pond	D	*	* & 550
Nonquit Pond	C	1,300	2,800
Total		113,050	57,250

* Close with a sand dike.

* * Maximum amount of boom required for ebb-tide, which is estimated to be slightly higher than flood-tide requirements.

* * * Maximum amount of boom required for flood-tide, which is estimated to be slightly higher than ebb-tide requirements.

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EXPLANATION OF TERMS USED

The following provides explanations and definitions for the terminology used in the discussion of protection strategies for the tidal inlets.

Beach Morphology

The typical beach morphology found in Rhode Island is illustrated in Figure 6. Sand beaches are normally planed off flat during storms. Gravel beaches typically are steeper and have a steep berm at the high-tide line.

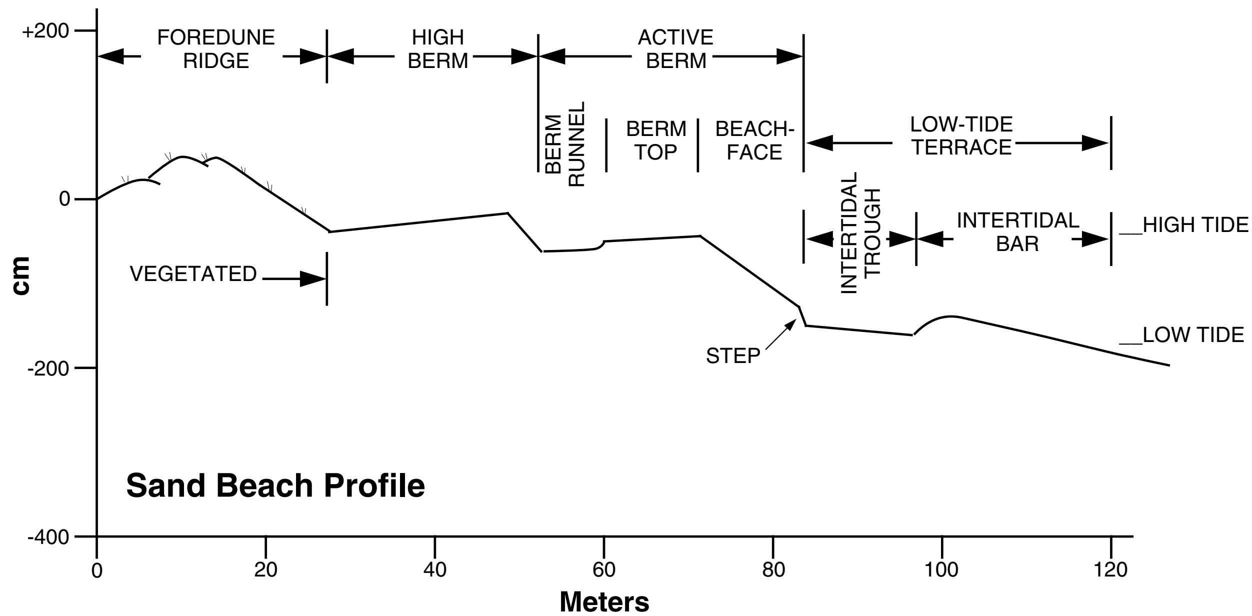

FIGURE 6. Nomenclature used for the sand beaches.

Coastal Sediments

Coastal sediments are classified into three general categories according to the dominant size of the individual clasts: (1) gravel, mean size greater than 2.0 mm; (2) sand, mean size between 0.0625 and 2.0 mm; and (3) mud, mean size less than 0.0625 mm.

Other Commonly Used Terms

Some additional terms that are used in the descriptions of the coastal inlets are defined as follows:

Anchor point. Stabilized position to which the line of booms is attached.

Berm (on a beach). A wedge-shaped sediment mass built up along the shoreline by wave action. Typically has a relatively steep seaward face and a gently sloping landward surface. A sharp crest (berm crest) usually separates the two oppositely sloping planar surfaces on the top of the berm. There are frequently two berms present, a high berm, the most landward, oldest berm, and an active berm, the most seaward and most recently activated berm (Figure 6).

Collection point. Zone along the shoreline where oil is directed so it can be collected from water surface or cleaned up. An example would be a hard-packed, fine-grained beach from which oil contamination can be readily recovered.

Deflection boom. A floating barrier designed to direct the flow of oil to a suitable collection point so that it can be recovered. The boom is set at an oblique angle to the primary flow direction. The angle is dependent on the velocity of the currents.

Ebb-tidal delta. Lobate accumulation of sand at the seaward margin of the primary entrance channel to a tidal inlet. Formed as a result of deceleration of ebb-tidal currents. Modified by waves.

Flood-tidal delta. Lobate accumulation of sand at the landward margin of the primary entrance channel to a tidal inlet. Formed as a result of deceleration of flood-tidal currents.

Geomorphic class. Type of inlet based on its geomorphic evolution (e.g., washover channels; river mouth entrance).

Groin. A shore protection structure built perpendicular to the shoreline, intended to trap littoral drift and retard erosion of the shore (W.F. Baird, pers. comm.).

Inlet class. Ranking of inlet based on degree of difficulty for containing and collecting spilled oil within the inlet (see Table 2).

Inlet throat. The deepest portion of the channel that connects the ocean to the mainland water body in a tidal inlet complex. Deep scour is the result of the accelerated flow of ebb- and flood-tidal currents in the constricted entrance channel.

Intertidal boom. Boom designed to lay on intertidal surface at low tide and to prevent entrainment of oil under the boom on a rising tide.

Jetty. A structure extending into a body of water, designed to provide access to an onshore berth (W.F. Baird, pers. comm.).

Knot. A unit of speed in navigation equal to one nautical mile per hour (1.852 km/h) (W.F. Baird, pers. comm.).

Longshore sediment transport. Sediment moved on the beach and in the nearshore zone by currents generated by breaking waves.

Main ebb channel. Deep channel through ebb-tidal delta, scoured by ebb-tidal currents, that projects seaward directly away from the inlet throat (see Figure 3).

Marginal flood channel. Component of ebb-tidal delta resulting from horizontal segregation of tidal current flow. Ebb-tidal delta usually has two marginal flood channels which are oriented obliquely to the main ebb channel and roughly parallel to the adjacent beaches (see Figure 3).

Protection boom. Boom designed to keep oil away from some feature, such as a fringing salt marsh. Not designed specifically for deflection or collection.

Riprap. A layer of randomly placed cobble- to boulder-sized fragments of rock designated to prevent erosion or scour of a structure, embankment, or foundation (W.F. Baird, pers. comm.).

Salt-water marsh. Growth of herbaceous plants subject to inundation of salt water during a tidal cycle.

Seawall. A structure separating land and water areas, designated primarily to prevent erosion and other damages due to wave action (W.F. Baird, pers. comm.). Usually vertical and composed of concrete.

Skimmer. Mechanical device designed to float on water and remove oil or oily water mixtures from the water surface.

Spit. Linear inter- or supratidal sediment body built by wave action. Typically composed of multiple curving beach ridges that project away from the dominant wave approach direction.

Tidal channel. Permanent channel located within the intertidal zone that serves as a conduit for the rising and falling tide. These channels usually migrate slowly.

Tidal prism. The total volume of water that flows into and out of a bay, harbor, or estuary during one tidal cycle.

Tide. The periodic rising and falling of the water that results from gravitational attraction of the Moon and Sun and other astronomical bodies acting upon the rotating Earth (W.F. Baird, pers. comm.).

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REFERENCE CITED

Boothroyd, J.C., N.E. Friedrich, and S.R. McGinn, 1985, Geology of microtidal coastal lagoons: Rhode Island: Special Publication, Marine Geology, Elsevier Pubs., Amsterdam, pp. 35-76.

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