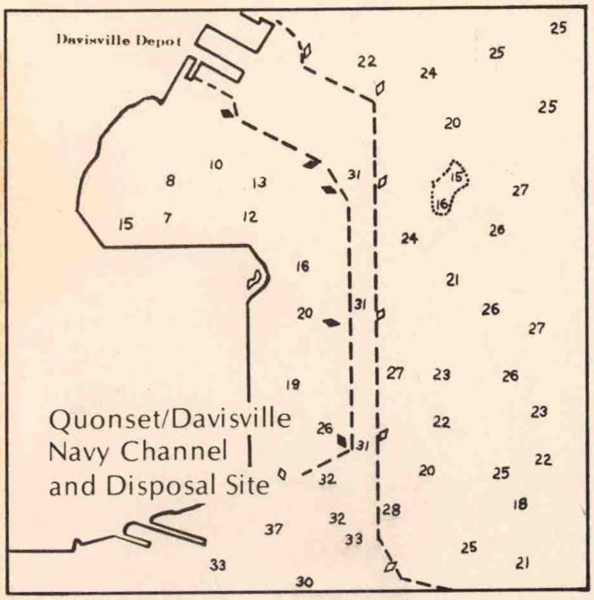

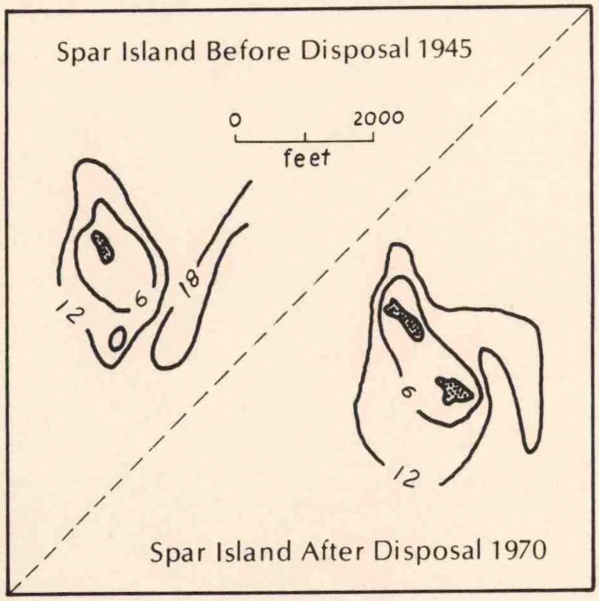

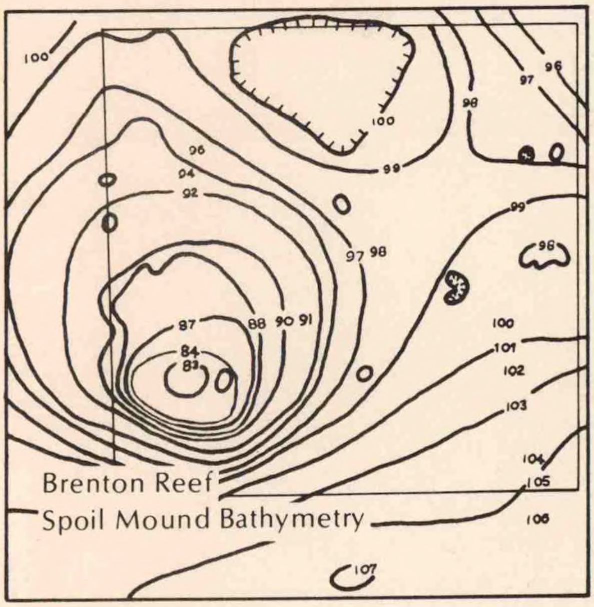

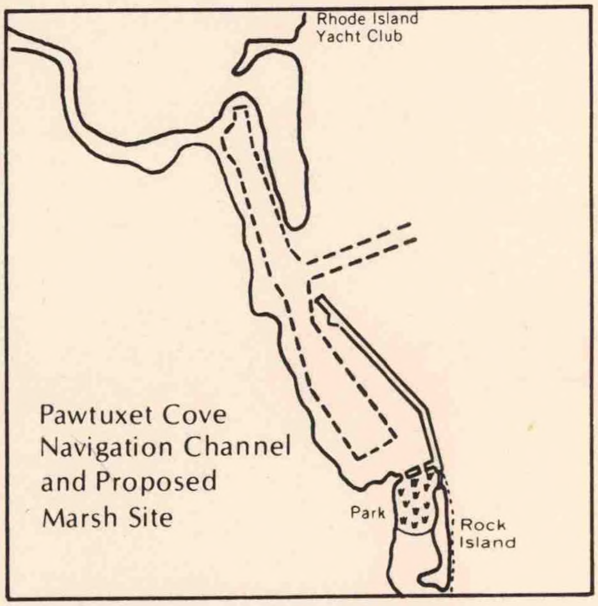

The Disposal of Dredged Material in Rhode Island:

An Evaluation of Past Practices and Future Options

G. L. Seavey
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Coastal Resources Center
University of Rhode Island
Marine Technical Report 72

Figures on Front Cover

Upper Left

Quonset/Davisville area and the Navy ship channel initially dredged in the 1940s, from nautical chart #13221 of Narragansett Bay. Small mound 15 to 16 feet deep in upper right-hand corner is an area of dredged material disposal. (See Figure 3 in text.)

Upper Right

Graphic outline of Spar Island in Mount Hope Bay and surrounding bathymetry before and after it was used as a disposal site for Mount Hope Bay channel sediments. Taken from Fall River Draft EIS.

Lower Left

Bathymetric contours of the dump site at Brenton Reef, Rhode Island Sound, taken in 1976, five years after it was used for the large Providence River improvement dredging project.

Lower Right

The Pawtuxet Cove navigation channel and anchorage, scheduled for maintenance dredging in 1979. A proposed salt marsh building location, which will make use of the dredge spoils, is shown at the bottom between the mainland and Rock Island.

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AUTHOR CREDITS

George L. Seavey is a Marine Resources Specialist with the Coastal Resources Center, Division of Marine Resources, at the University of Rhode Island. He has worked with the Coastal Resources Management Council since 1975 on the development of Rhode Island's Coastal Management Program.

Sheldon D. Pratt is a Research Associate in the Division of Marine Resources, University of Rhode Island, specializing in benthic ecology. He has conducted several dredging and disposal studies in New England since 1970.

PREFACE

The Rhode Island Coastal Management Program has long recognized that the dredging of harbors and navigational channels and the disposal of dredged materials is one of the most pressing problems facing those charged with the management of coastal resources. Concerns for the environmental impacts of dumping dredge material in Rhode Island Sound that have been voiced by fishermen and environmental interests have halted this method of disposing large volumes of spoils. Persons proposing small-scale dredging projects are finding it very difficult or impossible to find acceptable means for disposing of their spoils near or onshore.

In response to these problems the URI Coastal Resources Center, at the request of the Coastal Resources Management Council, has made a careful evaluation of all available information on the impact of past spoil disposal practices in Rhode Island waters. The considerable data generated by various agencies and researchers has now been compiled and reviewed so that a realistic and informed appraisal of the impacts of traditional disposal practices can be made. The volumes and quality of sediments in areas that need to be dredged have also been reviewed. Finally, unconventional techniques for using dredge materials for building salt marshes and islands have been examined for their applicability in Rhode Island. Several sites have been identified as possible candidate areas for these disposal methods.

We hope that this report, by providing a comprehensive view of the dredging problem, will help identify the key issues and the most promising solutions. The present impasse must be overcome if we are to have viable ports in the future.

Stephen Olsen

Stephen Olsen
Coordinator
Coastal Resources Center

SUMMARY CONCLUSIONS AND RECOMMENDATIONS

1. The dredging and dredged material disposal impasse is creating severe economic problems in Rhode Island. Dredging must be undertaken soon in several areas along the Providence commercial waterfront if this area is to remain competitive with other ports and harbors along the eastern seaboard. The lack of disposal areas(s) for this material has already limited or indefinitely delayed the development and expansion programs of the Providence Port Authority and several private corporations dependent on navigable waterfront. We recommend that a task force be created to bring together the responsible regulatory agencies and key individuals with concern for the environmental impact of dredged materials disposal. The task force would be charged with finding solutions for the disposal of spoils produced by large-scale dredging projects. A disposal site should be agreed upon, as well as the dredging and disposal procedures and the time frame within which the work should be accomplished.

2. We have attempted to classify the sediments found in several projected Rhode Island dredging areas using sediment core data supplied largely by the Army Corps of Engineers. This classification scheme is similar to and is based upon a classification method formulated by the state of Connecticut. The scheme classifies sediments according to metal concentrations, grain size, hydrocarbon content, precise location within a given estuary, and other factors. If such a scheme is formally adopted and applied to Rhode Island sediments, it will serve to identify, on a consistent scale, the degree to which the sediments in any area are polluted. This will facilitate the identification and control of the environmental impacts resulting from any dredging project.

3. A review of the condition of former large-scale spoil disposal areas shows that, on the basis of existing information, no substantial adverse environmental consequences to adjacent areas or the overlying water column have occurred as a result of spoil disposal even when these activities involved significant volumes of contaminated material. Since these dumping grounds can potentially accommodate significant volumes of additional material, and because they have already been altered from their original condition, renewed use of these areas should be considered.

4. It appears that the only practical solution at the present time for the disposal of large volumes of dredged material is to transport it offshore to a designated dumping ground. However, the possibility of enlarging an existing spoil island in Mount Hope Bay should be thoroughly examined as to its political, economic, and engineering feasibility. Such a use of the large amounts of dredged material from the Mount Hope Bay/Taunton River estuary would largely solve the disposal problem in this area.

5. Exciting possibilities exist to create salt marshes and small islands and to replenish beaches and eroded shorelines by using dredged materials from many small dredging projects around the state. These alternatives to traditional disposal methods are commonly used in other parts of the country but have not been seriously considered in the New England region. A preliminary screening of sites in Rhode Island indicates that there are many excellent candidate areas for these techniques. This report recommends that two such projects, at Pawtuxet Cove and in Point Judith, be given immediate consideration.

6. Additional specific recommendations are as follows:

   A. Sediments identified according to the proposed classification method as potentially degrading should be covered with a layer of cleaner material if they are disposed offshore. This greatly reduces any possibility of contamination to surrounding areas.

   B. There is no excuse for "short" or inaccurate dumping or spillage such as occurred in the past during dredged material transport offshore; precision dumping can be assured and monitored using readily available electronic equipment.

   C. Selected offshore disposal sites should not be located on or directly adjacent to the major commercial trawling grounds or show high sediment resuspension potential due to bottom currents and wave energies.

   D. Inshore disposal areas should not be located adjacent to commercial or recreational shellfish beds. Properly designed containment and turbidity control measures should be undertaken to assure that incohesive sediments with high water content do not migrate from the disposal site.

I. INTRODUCTION

A major problem facing coastal resources management in Rhode Island is the disposal of dredged materials. Until the late 1960s, dredged materials produced from innumerable projects were disposed of as expeditiously as possible with little regard for the long-range and potentially complex environmental impacts. However, more recent concerns over the possibility of water quality degradation and impacts on fisheries have virtually halted all dredging projects since 1971. Many badly needed dredging projects in navigation channels in the upper Bay and in harbors throughout the state continue to be postponed. The great majority of these projects are for maintenance dredging* of anchorages which have long been in use but which behave as settling basins for fine sediments. There are relatively few projects that require new channels, new anchorages, or other types of improvement dredging.*

The biggest problem in the present dredging impasse is finding a suitable disposal site for the dredged materials, much of which is contaminated with hydrocarbons, heavy metals, and toxic chemical compounds. A site near Brenton Reef (south of Newport in Rhode Island Sound) served as a disposal area for large quantities of material from the Providence Channel from 1967 to 1970. This site has since been closed due to opposition from fishermen and comments from the U.S. Environmental Protection Agency indicating that placement of the dredged material in the Sound would violate state water quality standards (Chase, 1977). A total of some ten million cubic yards were dumped at the Brenton Reef site. Prior to 1967, three to five million cubic yards had been dumped at nearshore and inshore locations within Narragansett Bay. Only five dredging projects, totalling 198,000 cubic yards, have been completed in Rhode Island since the Brenton Reef dumping ground was closed.

A proposed regional disposal area southeast of Brown's Ledge in Rhode Island Sound has been opposed by some fishermen and residents of the Massachusetts islands. This has forestalled a final decision on the suitability of the site, and thus further postponed dredging projects in southern Massachusetts (Fall River and New Bedford) as well as in Rhode Island. In the meantime, siltation continues in shipping channels and harbors. The economic cost of not dredging is placing increasingly heavy financial burdens on the port of Providence and the state of Rhode Island and is also causing great inconvenience to recreational boaters.

*"Maintenance dredging" refers to removal of sediment which has accumulated in previously dredged channels. "Improvement dredging" refers to the digging of entirely new channels or the deepening of existing ones.

The recently adopted Management Plan of the Rhode Island Coastal Resources Management Council recognizes the significance of the dredging and dredged material disposal problem in Rhode Island. The Council has established policies which favor ocean dumping (at sites such as Brown's Ledge or Brenton Reef) as a means to dispose of large volumes of material providing that specified environmental standards are met. The Council has also endorsed efforts to investigate innovative solutions to the disposal problem. These include such programs as salt marsh and island building, beach nourishment, and similar techniques, many of which are being used successfully in other parts of the country. The Council recognizes that dredging and spoil disposal will always be a problem unless long-term solutions are found. This report has been prepared for the Council as a first step toward breaking the present impasse and finding the long-term solutions to the dredging problem that this state so sorely needs.

The purpose of this report is threefold:

1. to assess concisely the present condition of several spoil areas used in the past and identify the location, volumes, and condition of areas that are presently expected to be dredged;

2. to provide information that will assist in the evaluation of alternatives to ocean dumping, such as beach restoration and marsh establishment; and

3. to provide specific suggestions on the feasibility of applying various disposal techniques in Rhode Island and to recommend locations and techniques where demonstration projects might be considered.

II. SUMMARY OF PAST AND PENDING PROJECTS IN RHODE ISLAND

Past Projects

Corps of Engineers. Channels and harbors in Rhode Island waters have been dredged and redredged since Colonial times. As the size and draft of vessels has increased, deeper water has been needed to accommodate commercial navigation and to provide anchorages and berthing for increasing numbers of recreational boats. The biggest dredging projects have taken place in the past several decades and involved the dredging of about 20 miles of 35- to 40-foot channels to the Port of Providence and to Fall River, Massachusetts. Smaller-scale projects have included the dredging of Little Narragansett Bay in Westerly, Great Salt Pond on Block Island, Newport and Wickford Harbors, and Point Judith Pond in Narragansett. Most of these projects have been carried out with federal assistance by the U.S. Army Corps of Engineers upon request of local interests or the state. Table 1 outlines the Corps-sponsored dredging and disposal activities since 1949.

Compiled largely from Corps of Engineers files in Waltham, Massachusetts, Table 1 shows that for nearly 30 years Corps improvement and maintenance dredging has taken place in Rhode Island waters almost annually, and in some years several dredging projects took place simultaneously. Several general trends are clear:

1. Spoil disposal in the fifties to mid-sixties took place largely within Narragansett Bay (primarily off South Prudence). More recent dumping was concentrated further offshore, at Brenton Reef.

2. Early projects frequently used salt marshes or other coastal wetlands as disposal areas. This procedure was last seen in 1963.

3. Increasing complaints or dissatisfaction over many original Corps-selected disposal areas have required that alternative sites be used (Table 1, Block Island projects in particular).

4. Most dredging projects since 1966 have been undertaken to reestablish the navigability of existing channels and harbors by dredging to previously approved depths (maintenance dredging). Most improvement dredging projects have deepened or widened already existing channels. Little recent dredging activity has occurred in previously undisturbed areas.

5. Of the eight projects undertaken since 1971, most have been relatively small scale (less than 50,000 yd^3) and seven have occurred in areas containing relatively clean sediments and high water quality classifications.

TABLE 1

SUMMARY OF ARMY CORPS-SPONSORED NAVIGATION PROJECTS IN RHODE ISLAND (1949-1977)

NOTE: This information was obtained primarily from Army Corps of Engineers Project Engineering Office and Environmental Analysis Branch files at the New England Division in Waltham, Mass. Since some of these data came from specification sheets established for a project prior to its completion, some changes in total amounts of material dredged and disposal locations may have occurred.

Year	Area Dredged	Approx. Vol. of Spoils (1000's of yd^3)	Project Type	Present Water quality	Disposal Technique/Site
1977	Pt. Judith Channel & Port Facility	72	Improvement	SA	On land sites A & B (Galilee)
1977	Little Narragansett Bay (Stonington, CT)	12.5	Maintenance	SB	Sidecast on site
1976	Block Island Harbor of Refuge	20.8	Maintenance	SB	Off SE Pt. 41° 08' N. Lat. 71° 28' W. Long. Site changed from original due to opposition
1975	Prov. River Channel (upper bay)	50-55	Maintenance (removal of unclassified material)	SA/SB	Dumped in deep hole in channel - originally slated for Brenton Reef dump site
1974	Block Island Harbor of Refuge - channel entrance only	5	Maintenance	SA	Sidecast on site
1973	Fall River Harbor	---	Maintenance (removal shoal)	Mass. waters	on land in Battleship Cove
1972	Block Island Great Salt Pond	55	Maintenance	SA	Clamshell-sea disposal halfway to north light - changed from original due to opposition
1971	Pt. Judith Harbor of Refuge	19.7	Maintenance 15 ft. channel	SA	Brenton Reef

TABLE 1 (cont.)

Year	Area Dredged	Approx. Vol. of Spoils (1000's yd^3)	Project Type	Present Water quality	Disposal Technique/Site
1967-1971	Providence River Channel & Harbor	9,800	Improvement (40' channel)	SA/SD	Brenton Reef and other designated sites in vicinity
1969	Pt. Judith-Harbor of Refuge	35	Improvement to 15' for 1 mile	SA	At 3 sites on state beach at Sand Hill Cove
1968	Block Island - Harbor of Refuge	25	Maintenance - 15' channel	SB	Off SE Point; site changed from original due to opposition/clamshell dredge
1966	Warwick Cove	289	Improvement - 6 foot channel, 4 anchorages	SB	52,000 yd^3 pumped onto Oakland Beach. The remainder dumped at approved grounds SE of Prudence Island in deep hole
1966	Pawtuxet Cove (Rock removal, 3 locations)	15	Improvement follow up to project below	SC/SD	SE Prudence Island site
1965	Pawtuxet Cove	207	Improvement 6 foot channel, 14 acre anchorage	SC/SD	SE Prudence Island Site
1964	Wickford Cove	23	Maintenance - 9 foot channel to Rte. 1 Bridge	SB	SE Prudence Island Site
1964	Prov. River (Rumstick Neck to Bullock's Point Reach)	273	Maintenance - all material lying above 37 ft. below MLW	SA/SC	SE Prudence Island Site
1963	Pt. Judith Pond & Harbor of Refuge	47	Maintenance - 15 ft. channel	SA	Hydraulic - on Sand Hill Beach and Galilee marsh
1963	Fall River Harbor	388	Maintenance - 35 ft. channel from State Pier to Shell Oil Co. dock	Mass. waters	SE Prudence Island Site
1963	Apponaug Cove	88	Improvement - two 6 foot channels and anchorage	SC	Bucket Dredge - to SE Prudence Island Site
1963	Wickford Harbor	77	Improvement	SB	Hydraulic-on land

TABLE 1 (cont.)

Year	Area Dredged	Approx. vol. of Spoils (1000's of yd^3	Project Type	Present Water quality	Disposal Technique/Site
1963	Block Island Harbor of Refuge	21.5	Maintenance	SB	In Block Island Sound - east of line joining East Breakwater light and Bell buoy 1 - not over 0.6 nautical miles
1963	Block Island - Great Salt Pond	23.7	Maintenance	SA	Hopper Dredge
1962	Pawcatuck River	1.2	Rock Removal - in channel No. of Sandy Point	Conn. waters	In public dumping ground in Fisher's Island Sound.
1961	Pawcatuck River (shoal areas)	3 lots - total of 100	Maintenance to 10 feet	SA/SB	At Stonington dumping ground in Fisher's Island Sound.
1960	Prov. River & Harbor	3 lots - total of 448	Maintenance to 35 feet channel between Sabin Pt. & Fox Point	SC/SD	SE Prudence Island Site
1959	Fall River Channel and Tiverton Pool	----	Removal of unclassified material to 35 feet	SB/SD	SE Prudence Island Site
1959	Bullock's Pt. Cove	184	Improvement - 6 ft. & 8 ft. channel & 2 anchorages	SC	At 3 designated on land disposal sites in immediate vicinity
1958	Pt. Judith Pond/ Harbor of Refuge	66.5	Maintenance of Channels	SA	At 4 designated on land disposal sites in immediate vicinity
1957	Fall River Harbor	1,500	Improvement - 35 ft. channels	Mass. waters	SE Prudence Island Site
1957	Sakonnet Harbor	41	Improvement - 8 ft. deep anchorage	SA	Scheduled for approved dump site to West at 59-65 ft. depth
1956	Block Island - Harbor of Refuge	32.6	Channel Maintenance	SB	At 2 offshore locations and on land adjacent to U.S. Coast Guard Station

TABLE 1 (cont.)

Year	Area Dredged	Approx. Vol. of Spoils (1000's of yd^3)	Project Type	Present Water quality	Disposal Technique/Site
1956	Pt. Judith Pond	60.7	Maintenance	SA	At Sand Hill Cove Beach and north of Pier 3
1955	Prov. River & Harbor	186	Maintenance Sabin Pt. to Fox Pt.	SC/SD	SE Prudence Island Site
1954	Fall River Entrance Channel	62	Maintenance to 37 ft. MLW	Mass. waters	Disposal in channel in deep hole
1952	Block Island - Salt Pond & Harbor of Refuge	?	Maintenance	SB	Mostly offshore. Some may have been placed onshore at local request
1950	Pt. Judith Pond & Harbor of Refuge	2 lots.125 & 64.5	Improvement	SA	9 Designated spoil areas in immediate vicinity on land - mostly in low lands and marshes
1950	Fall River channels	2,710	Improvement Deepen entrance channels	Mass. & R.I. waters	Several spoil areas in vicinity: - Spar Island - Brayton Point -Somerset Shipyard -in cove at Shell oil -Fall River Country Club -Common Fence Point
1949	Pawtucket (Seekonk River)	32	Maintenance - channel	SD	SE Prudence Island Site
1949	Prov. River & Harbor	115	Channel Maintenance - Sabin Pt. and Fox Point	SC/SD	Hopper Dredge - to SE Prudence Island Site
1948-1949	Pawcatuck River	178	Improvement-Channel to Watch Hill Cove	SA/SB	No clear record of disposal-probably went to designated dumping grounds off Stonington, CT
1948-1949	Pawcatuck River	87	Improvement-Channel from Watch Hill Cove to Westerly	SC	

Private and municipal. In addition to the Corps channel improvement and maintenance dredging projects, significant dredging has been undertaken outside designated channels by private interests such as oil companies or marinas, and by municipal and state governments. While usually not as large in scale as Corps projects, private and municipal dredging and disposal efforts have often resulted in more visible and longer-lasting alterations to the coastal waterfront. Table 2 identifies the types of private and municipal dredging activities undertaken between 1974 and 1978. A Marinas Task Report recently completed by the State's 208 Program states that over 80 percent (125) of all existing marinas established in Rhode Island have required dredging as part of the initial facility siting (Statewide Planning Program, 1978).

TABLE 2

PRIVATELY SPONSORED DREDGING ACTIVITIES FROM 1974 to 1978

(Corps of Engineers Permit Files)

Year	Area	Applicant	Amount/purpose	Disposal
1977-78	Old Warwick Cove	Fred Freese	14,000 yd^3 shells & silt to 4 ft. below MLW (anchorage area) 180' x 94'	To be used as fill
1977-78	Fort Wetherill	Town of Jamestown	400 yd^3 (40' x 90') to 11 ft. depth - to make boat basin	Disposal in adjacent area & covered with clean fill
1977-78	Providence River	Marquette Cement Co.	2500 yd^3	Assent issued but work hasn't been undertaken
1977-78	Pt. Judith Pond	Piedmont Realty (Kenport Marina)	Make additional boating slips	Fill in back of property - case being contested by state due to possible encroachment on public lands
1977-78	Jamestown	Wharton Shipyard	2300 yd^3 of mud to fine sand. 375' x 30' x x 10' depth. Anchorage maintenance	Hydraulic -used for fill above MHW behind Racquet Road
1976	Greenwich Cove	E.G. Yacht Club	1000 yd^3 to depth of 6 ft. below MLW	Clamshell or dragline - disposal at municipal sanitary landfill
1975	Providence River	City of Providence	2000 yd^3 - berth maintenance	Above MHW at Field's Point
1975	Providence River	Mobil Oil Corp.	250 yd^3	1600 ft. inland
1975	Potowomut River	A.W. Drew	30 yd^3 20' x 20'	Placed on own property
1975	Mt. Hope Bay - Portsmouth	Awashonks Realty	1100 yd^3 of sand - redredge 2 areas (60' x 60' and 110' x 85') also 150 yd^3 of clean fill	To be used as backfill
1974	Providence River	Mobil Oil Corp.	50,000 yd^3	Bulkheading

Proposed Projects

Corps of Engineers. There are 18 federal navigation projects in Rhode Island (Chase, 1977); these include channels, harbors, and breakwaters built and maintained for navigation purposes. Many of these projects have received improvement dredging by the Corps at least once, and some channels have been deepened or widened on numerous occasions (Table 1). Navigation channels continually silt in and must be redredged, sometimes as often as every five to six years, in order to maintain navigable depths. In recent years, however, only portions of the smaller-scale projects have been redredged. The Corps has identified 12 major dredging projects (both improvement and maintenance) that will probably be needed within the next ten years. These projects and the estimated volumes of spoils involved are listed in Table 3.

Table 3

CORPS-PROPOSED DREDGING PROJECT LOCATIONS AND VOLUMES

Location	Estimated volume (yd^3)
Fall River/Mount Hope Bay	2,000,000
Apponaug Cove	50,000
Block Island	
Harbor of Refuge	25,000
Great Salt Pond	50,000
Bullock's Point Cove	80,000
Little Narragansett Bay and Watch Hill Cove	20,000
Newport Harbor	30,000
Pawtuxet Cove	50,000
Providence River	200,000
Seekonk River	100,000
Wickford Harbor	40,000
Point Judith Harbor of Refuge	30,000
Total	2,675,000

Taken from 208 authorized Areawide Water Quality Management Plan: Preliminary Evaluation of the Water Quality Impacts of Hydrologic Modifications, 1977.

The Fall River Harbor/Mount Hope Bay project is the largest of the pending projects and involves more than 75 percent of the total material that is slated for dredging in the Narragansett Bay/Mount Hope Bay area. Only about 50 percent of the materials from this project would be removed from Rhode Island waters, however (from the Mount Hope channel and the

Tiverton waterfront, known also as the Tiverton Pool). The remaining 50 percent would come from Massachusetts waters in the upper reaches of the Bay and along the Fall River waterfront on the Taunton River (H. Guptill, personal communication).

The Fall River/Mount Hope Bay project proposal involves deepening the existing 35-foot channel to 40 feet and is thus classified as an improvement dredging project. Most of the material that would be dredged was deposited prior to the industrialization of the estuary and can be considered relatively clean. The existing channel was dug to its present depth of 35 feet in 1949 and has been maintained on several occasions thereafter. According to the Corps, the proposed deepened channel would accommodate larger vessels and could conceivably result in a boost to the region's economy of more than $3 million/year (H. Guptill, personal communication).

The large scale of the Fall River project and the lack of disposal site(s) for the dredged materials are presently the major deterrents to this project. The states of Rhode Island and Massachusetts are in disagreement over the use of the proposed Brown's Ledge offshore dumping site or other disposal alternatives. In the past, spoils from this area were dumped off Prudence Island within Narragansett Bay and at several sites in Mount Hope Bay, including Spar Island and Common Fence Point in Rhode Island. Reuse of these and other disposal sites has not been seriously considered.

Although Fall River is the largest and potentially one of the most significant proposed dredging projects, it is not considered the highest priority by the Corps. The only project which the Corps is considering in fiscal year 1979 is maintenance dredging in Pawtuxet Cove (C. Boutilier, personal communication). This is a comparatively small-scale project but involves a recreation anchorage that is badly in need of dredging; the spoils contain considerable amounts of polluted sediments. No disposal plans had been finalized by January 1979, although draft engineering design plans have been presented to state and local officials.

The disposal situation in Rhode Island is complicated by the fact that only some six percent of the materials designated for dredging originate in water areas classified as "clean" or meeting SA criteria. This has placed additional restraints on efforts to establish appropriate disposal locations.

Private and municipal. A number of private and municipal projects are presently awaiting approval from permitting agencies. Some of these are being held in abeyance pending the designation of an approved open water disposal site. As Table 4 shows, many of these projects are small in comparison with the Corps maintenance dredging projects, but most applications are for work in many of the same lower water and sediment quality areas, thus presenting similar disposal difficulties. It should be noted, however, that two of the projects are large and have been held in abeyance for several years. Another large project application has recently been withdrawn, possibly due to the lack of a disposal site.

A Historical Perspective

Figure 1 shows the major dredging/disposal sites in Rhode Island waters and identifies major onshore and offshore locations where spoil disposal has occurred. Although most of the disposal locations have been used only once, those at South Prudence, Brenton Reef, and Block Island have received spoils on many occasions. It is obvious from this figure and the foregoing tables that dredged material disposal has been a major activity in our coastal region for many years.

Most onshore disposal activities have occurred directly along the waterfront and have resulted in extensive areas of bulkheading, especially in heavily urbanized areas such as the Providence waterfront. In urban areas, dredged spoils have formed the existing coast line and have had a positive impact on industrial and other high-intensity uses. Using dredged material in this way solved the problem of what to do with the spoil in a productive fashion. Unfortunately, it also resulted in the loss of stretches of natural coast line that were often picturesque and biologically valuable. Since waterfront industrial or commercial land is not anticipated to increase substantially in Rhode Island, there appears to be little opportunity to use large amounts of dredge material for bulkheading in the future. Dredged spoil has also been used on the shore around marinas and public access areas such as boat-launching ramps, which also frequently require some form of bulkheading, riprap, or other shoreline stabilizing device. Spoil has also been pumped hydraulically onto many coastal wetlands and islands. These activities have likewise had considerable impact on the coastal environment.

There has been little use for dredged materials in upland or inland locations in Rhode Island. Although experiments with the use of spoil as landfill cover, for agricultural use, and in reclaiming mined land have been successfully undertaken in other parts of the country (largely Corps of Engineers research projects), they have not as yet been seriously considered in Rhode Island. The applicability of spoil for such uses in Rhode Island is greatly dependent on the proposed disposal location and on the content of the material to be

TABLE 4

PRESENTLY PENDING APPLICATIONS BEFORE THE CORPS

FOR PRIVATELY SPONSORED DREDGING ACTIVITIES

Area	Applicant/Number	Amount/Purpose	Disposal
Bullock's Cove East Providence	Cove Haven Marine #13-77-0680	8960 yg^3 sandy silt/dredge and floats	On-land disposal on the property
Providence River/ Off Allen's Ave.	ATC Petroleum #13-76-0151	8000 yd^3 silt/dredge - ship berth	State assent given - no disposal site. Application now closed - withdrawn by applicant
Providence River/ Off Allen's Ave.	Texaco, Inc. #13-77-0231	140,000 yd^3 - ship berth - desires to go to Brenton Reef or other open site	No open water disposal site available - application withdrawn
Warren River	Wharf Tavern, Inc. #13-75-0232	150 yd^3	Disposal proposed on land - application withdrawn
Providence River	City of Providence #11-74-0087	494,000 yd^3 - port improvement	No disposal site available - pending since 1974.
Providence River	Providence/Worcester Co. #11-74-0043	287,000 yd^3 - to construct a quay by filling 47 acres of tidal flowed land within harbor lines	State and Corps have issued permits. Presently being held in abeyance due to disagreement between Corps and Department of Interior Fish and Wildlife Service
Providence River	Gulf Oil Corporation August 8, 1978	5300 yd^3 - dredge to 41 ft. MLW - fine gravel material for ship berth	Plan to dump material near New Haven, Connecticut
Stillhouse Cove, Cranston	Rhode Island Yacht Club #13-78-608 October 31, 1978	4400 yd^3 silty sand	Hydraulic dredge - pump behind bulkhead on property
Newport Harbor	Newport Offshore Limited October 1978	150 yd^3 dredge clean gravel	Bulkhead and fill on property

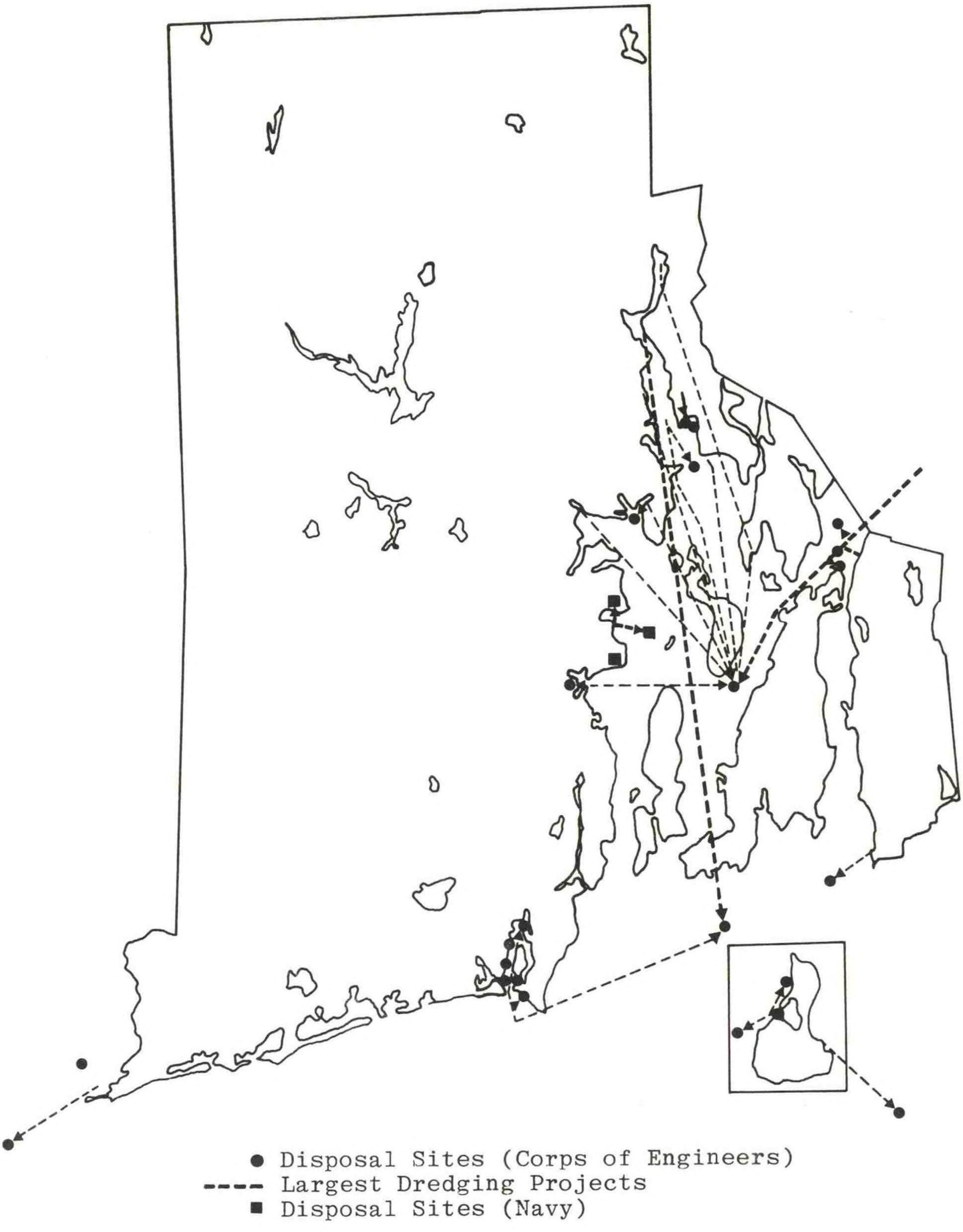


Figure 1. Major dredge disposal locations in Rhode Island waters.

disposed (its classification as a hazardous or non-hazardous waste), particularly as it pertains to effects on ground and surface waters (J. Quinn, personal communication). Conceivably, if dredged material can be identified by the Department of Environmental Management as a non-hazardous waste, it can be disposed in existing licensed municipal or private sanitary landfills.

Open water disposal in nearshore and offshore locations has been extensive. Prior to 1971, when most of the large-scale dredging projects occurred, great amounts of material were deposited in several dumping grounds off Block Island, in a deep portion of the East Passage south of Prudence Island, and at Brenton Reef (Table 1). South Prudence was last used in 1966, and since 1971 the use of the offshore sites has been largely curtailed due to opposition from commercial fishing interests and general environmental concerns. During this period, many investigations of these sites (particularly Brenton Reef) have been undertaken by the Army Corps of Engineers, the Environmental Protection Agency, and the University of Rhode Island. In general, these investigations (which are summarized in Section IV of this report) show that species composition and sediment type at the dump sites have changed since dredged material has been deposited there. It has been difficult, however, to find evidence that use of these offshore sites for dredge disposal has had any measurable impact on adjacent areas of the Bay or the Sounds, on their water quality or their fisheries.

III. DREDGING TECHNOLOGY AND REGULATION

Methods and Costs

Dredging in the marine environment is accomplished through the use of mechanical or hydraulic dredges. Mechanical dredging usually involves bucket or clamshell devices which scoop bottom materials onto barges or, if near shore, to trucks for transport to a disposal area. Turbidity is created at the dredging site, but if the sediments are cohesive, turbidity is kept at low levels (Morton, 1977). Turbidity during disposal at an open water site is minimized if a bucket dredge is used, since the cohesiveness of the sediment is retained. Mechanical dredging has been used in many Rhode Island projects.

Hydraulic dredging is commonly used for large-scale channel maintenance projects on the southeast and Gulf coasts and involves sucking sediments from the bottom into a hopper or through a pipeline to a nearby disposal site. The technique has been used in several Rhode Island dredging projects including Point Judith Pond and Mount Hope Bay channels. The method creates considerable turbidity when the material is disposed in open water because a slurry is formed that can be as much as 90 percent water. Technological advances such as the use of containment areas and silt curtains are reducing this problem, however. Hydraulic dredging is usually less costly than mechanical dredging.

Regardless of the methods used, dredging is an expensive undertaking, and costs rise dramatically as the distance the spoils are hauled and the amount of rehandling increase. Onland disposal is generally the most expensive, due to the rehandling from dredge to barge, then to truck and dump site. Offshore disposal eliminates some rehandling, but transport distances are frequently greater. Costs of dredging and disposal projects also vary greatly depending on the amount of time involved, the size of the project, and the type of sediments to be dredged.

The costs of dredging are increasing with time as well. When the Corps dredged the Providence River in 1967-71 and disposed of the spoils at Brenton Reef 20 miles away, the cost per cubic yard was approximately $1.87. A similar figure was determined by the Corps' New York District in 1970 for a project with similar dredging methods and transport distances. The cost data developed by the Corps for this latter project provide a useful comparison of the relative costs of methods and distances to a disposal site.

Estimated costs/yd - New York District 1970

Method	1 mile	3 miles	10 miles	20 miles	30 miles
Hydraulic (only for short distance)	$0.95	$1.30	---	---	---
Buckets and scows	$1.10	$1.25	$1.50	$1.80	$3.60

The rise in the costs of dredging are illustrated by calculations made when the Navy dredged the Connecticut River at New London in 1973-74. This was a large-scale project involving several million cubic yards of material. It cost \$3.16/yd^3 to dump the materials at the mouth of the estuary, a distance of 5 miles from the dredge site. Costs would have been \$4.00/yd^3 if the material required transport to a disposal site 15 miles further into protected water, and \$10.14/yd^3 to go 48 miles out into the open water of Block Island Sound (U.S. Navy, 1976).

In 1978 the Providence Port Authority removed sediments from around the commercial piers, loaded it onto trucks, and transported it approximately a half mile for disposal on an old spoil bank at Field's Point. C. E. McGuire, the engineering firm which designed and planned the project, estimates costs involved for sediment removal, hauling, and disposal at $7.50 per cubic yard (V. Calabretta, personal communication).

Regulations

Dredged material disposal is regulated by both state and federal agencies. The Rhode Island Coastal Resources Management Council has promulgated policies and regulations governing the disposal of materials which require an applicant to meet specified performance standards and to demonstrate that the project will have no significant adverse impacts on the environment, historic sites, or the local economy. Factors the Council considers of particular importance include changes in water circulation patterns, potential impacts on fishing grounds and nursery areas, biological oxygen demand (BOD), and damage to bottom communities. The Council has established an interim policy which prohibits dumping in the deep ocean (continental slope) until better environmental information on such activities is made available (Coastal Resources Management Council, 1978).

At the federal level, the U.S. Army Corps of Engineers Regulatory Branch in the Division of Operations is responsible for issuing permits for dredging and disposal activities. The Environmental Protection Agency (EPA), the National Marine Fisheries Service (NMFS), and the U.S. Fish and Wildlife Service provide review and comment to the Corps on each application. The EPA also implements the National Pollutant Discharge Elimination System (NPDES), which establishes water quality goals and criteria as part of the Water Pollution Control Act Amendments of 1972. The EPA can veto the use of any wetlands or other natural resource area for the disposal of dredged material (Federal Water Pollution Control Act, 1972). EPA plays a significant role along with the Corps in determining the suitability of materials for disposal, particularly in the marine environment. Together they have developed a manual describing procedures for conducting bulk analysis, elutriate tests, and bioassays on materials designated for ocean water disposal (Corps of Engineers/Environmental Protection Agency, 1977). The Corps is presently subcontracting bioassay studies and is trying to refine this newly developed methodology. They eventually hope to have bioassays completed for all of New England's major port areas. Once they are completed, an applicant for a dredging and disposal permit would then only have to show that the material involved is similar in character to that already analyzed without having to repeat expensive assays (F. Donovan, personal communication). Bioassays would still be required on materials found to be dissimilar in character or which are taken from known "hot spots" in side channels or berthing areas.

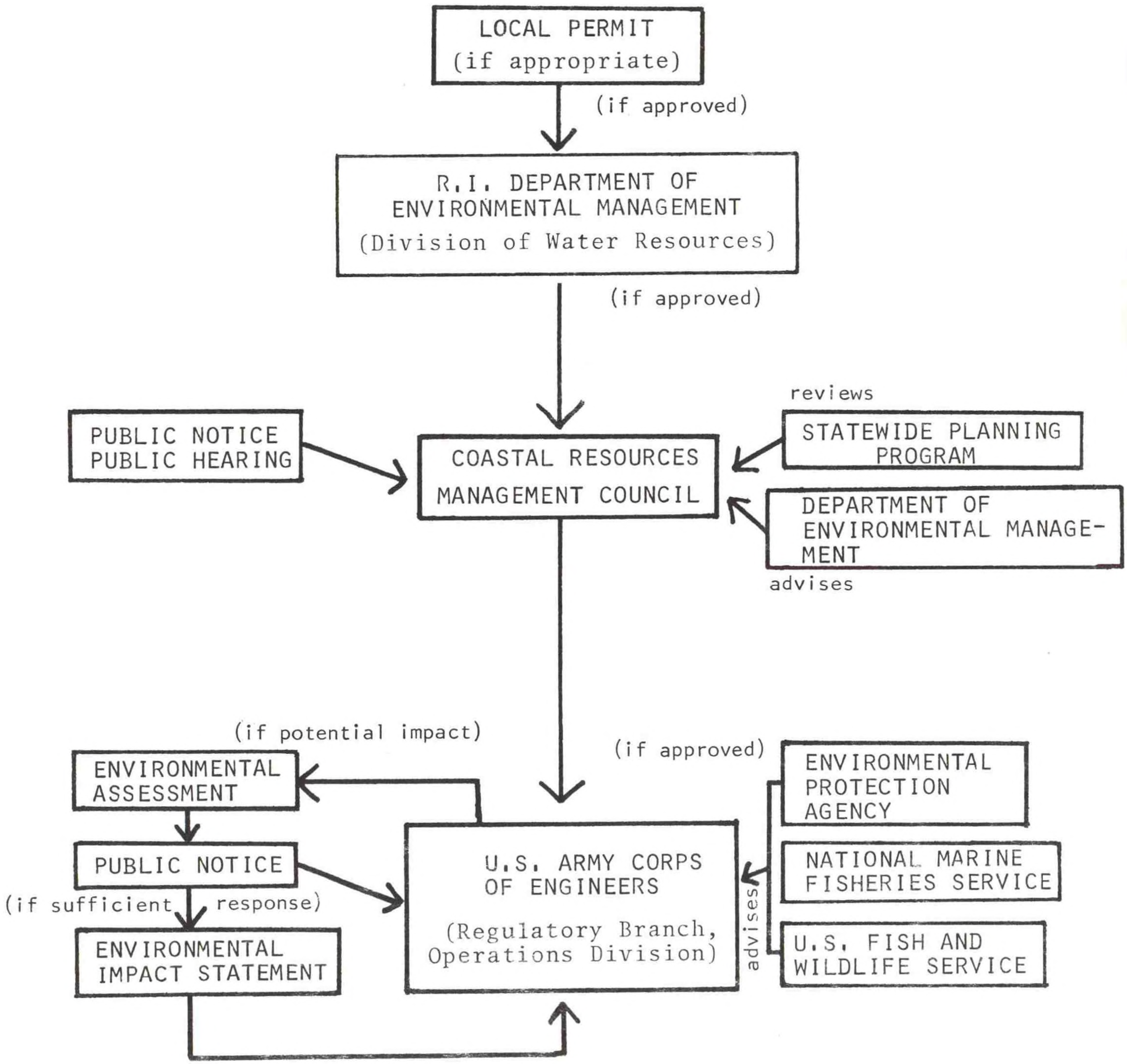
Figure 2 depicts the permitting procedure for non-federally sponsored dredging and disposal projects. Federally sponsored navigation improvement and maintenance projects must undergo similar multi-agency and environmental scrutiny, and in addition must have Congressional approval and have a favorable benefit/cost ratio.

The Need for a Spoil Classification Scheme

Effective regulatory control over sediment disposal gives assurance to the public that spoils will not seriously harm recreation or fisheries. This is especially important in Rhode Island, where there are many active commercial and recreational fisheries near all potential disposal sites. However, a regulatory program should not automatically prohibit the disposal of sediments in areas where the environmental and economic costs can be shown to be low. Nor

Figure 2

DREDGING PERMIT PROCESS



should regulations automatically prohibit the disposal of sediments containing above average levels of a given metal or compound when average levels in clean sediment are normally high. Agencies charged with regulation and control of spoil disposal activities need to consider such factors.

In attempting to address these difficult issues, the EPA in 1971 established criteria for evaluating dredged materials. They were based on a survey of harbor sediments in the Great Lakes. The Corps of Engineers subsequently issued a circular which applied these criteria to sediments dredged from all United States waters. The criteria established numerical concentration limits for the following seven variables: chemical oxygen demand, total Kjeldahl nitrogen, volatile solids, oil and grease, mercury, lead, and zinc (Corps of Engineers, 1978). Acceptable limits for volatile solids was 6 percent or less, that for lead or zinc was 50 parts per million (ppm) and one ppm for mercury. If the concentration of any one constituent exceeded the predetermined limit, the material was considered polluted and not acceptable for open water disposal. Considerable opposition to these initial criteria developed because they did not take into account the location of the contaminants in the dredged material, were not based on evidence of toxicity or environmental impact, and did not consider naturally occurring local or regional sediment variables. Nor did they consider a contaminant's "chemical mobility." This latter factor is extremely important because many contaminants are chemically bound to the sediments and thus may have limited impact on marine organisms. The criteria provided only for an inventory of the total amount of each contaminant found in the sediment.

In 1973, the EPA substituted the Elutriate Test for the total sediment analysis described above. This test measures the amount of pollutants released into the water from prolonged shaking of sediment samples. The Elutriate Test addresses the short-term water quality impacts caused by the dumping of spoil. At present, the Elutriate Test is supplemented by bioassays which are designed to define longer-term benthic impacts. There is presently some question as to whether even these tests can yield an accurate assessment of the impact of dredged material disposal.

The state of Connecticut has since developed a spoil classification method as part of their plan for dredged material disposal in Long Island Sound (Connecticut Department of Environmental Protection, New York Department of Environmental Conservation, 1977). Although this method is not based on specific evidence of toxicity to marine organisms, it does incorporate empirical data on sediment variables in the state's waters. The Connecticut classification method identifies levels of pollutants and provides a framework whereby the suitability of spoils for various disposal options may be determined. It also indicates when additional testing of materials for their potential environmental impact may be necessary. The state of Massachusetts, in its draft regulations for disposal permits, is following a similar classification mechanism.

The Connecticut plan recognizes three distinct sediment classes, as can be seen in the following table. Background levels of metals in the Central Sound are included for reference. (Note that the upper range limits for lead and the average levels of zinc found in naturally occurring Central Long Island Sound sediments exceed the 50 ppm acceptable limits for these metals established by the EPA in 1971.)

	Central Sound Sediment		Class I	Class II	Class III
	Average (ppm)	Range (ppm)			
Percent silt-clay			60	60-90	90
Percent water			40	60-60	60
Percent volatile solids (NED method)			5	5-10	10
Percent oil and grease (hexane extract)			0.3	0.3-1	1
Mercury (Hg)	0.5	--0.5	0.5	0.5-1.5	1.5
Lead (Pb)	27.8	6-63	100	100-200	200
Zinc (Zn)	87.8	2.3-214	200	200-400	400
Arsenic (As)	----	----	10	10-20	20
Cadmium (Cd)	1.3	1-2.9	5	5-10	10
Chromium (Cr)	28.8	2-108	100	100-300	300
Copper (Cu)	69.6	2-269	200	200-400	400
Nickel (Ni)	11.2	2-40.6	50	50-100	100
Vanadium (V)	----	----	75	75-125	125

Class I sediments are relatively coarse-grained and have a high solids content. They are defined by levels found in clean estuaries and Long Island Sound. These sediments are considered non-degrading to water quality and non-toxic to marine organisms. They may be deposited without restriction in regional dump sites. Class II sediments are relatively fine-grained and may be moderately enriched with pollutants. They may be judged either non-degrading or potentially degrading, but are considered suitable for island or marsh creation or for open water disposal if located in a stable area or if sediments are covered with cleaner materials. Class III sediments are fine-grained, have low solids content, and are frequently highly enriched with pollutants. They may be potentially degrading or hazardous and may require review through bioassay. Class III sediments found to be toxic cannot be dumped at sea but must be disposed on land or be suitably contained at inshore locations. Where various classes of spoil are found in a single dredge site, the pollutants present can be ranked according to their potential for environmental impacts. The order of ranking is as follows: percent oil and grease > percent volatile solids > percent water > percent silt/clay. For example, sediments containing Class I silt/clay, Class I water, Class II volatile solids, and Class III oil and grease would be classified as Class III material.

The inclusion of naturally occurring levels of heavy metals in the classification scheme is important because it provides a more accurate baseline from which "pollutants" may be measured. The mercury content of Class I Connecticut sediments is, for example, 0.5 ppm or one-half the 1971 EPA guideline level. On the other hand, the permitted levels of lead and zinc are 100 and 200 ppm, respectively (as opposed to 50 ppm permitted under the 1971 EPA criteria), because of the high levels commonly found in New England sediments.

Rhode Island sediments can be classified in a manner similar to the Connecticut scheme using data produced by the Corps of Engineers environmental assessment process for specific estuaries and harbors. These data provide computerized information on metals, solids content, percent hydrocarbons, and other variables taken from sediment cores from each area. Sediment variables are reported for both surface and subsurface samples. Data from the Corps computer files on each Rhode Island sample area are presented in Appendix A. Since Rhode Island and Connecticut sediments and pollution sources are similar, the Connecticut numerical limits are useful in identifying the relative contamination of Rhode Island sediments. Table 5 presents a summary of this information and shows the number of sediment cores which fall into each of the three spoil classifications.

TABLE 5

SUMMARY: APPLICATION OF A SPOIL CLASSIFICATION SCHEME TO EXISTING CORPS DATA ON SPOIL SOURCE AREAS

Location of Cores	Surface Sediment Classification			Subsurface Sediment Classification			Total # of Sample Stations	Discussion
	I	II	III	I	II	III		
Providence River								Upper Providence River surface sediments are contaminated with very high levels of volatile solids, zinc, copper, and lead. There are moderately high levels of most other pollutants with the exception of oil and grease. Subsurface sediments, although still warranting a Class III designation, show a consistent decrease in all pollutants. Cores taken from near Conimicut Point have sandier sediments than the upper channel and have consistently low metal levels. Moderately high water content prevents more of these sediments from being placed in Class I. In some cases, metal content increases with core depth, indicating that bottom currents have probably recently brought in cleaner sandier sediments.
Field's Point	-	-	3	-	-	2		
Pomham Rocks	-	-	1	-	-	1		
So. Conimicut Pt.	2	2	1	1	2	1	9	
Pawtuxet Cove	1	2	2	2	2	-	5	Sample PE-1, taken from the mid-cove area, contained a very high percentage of silt, clay, and volatile organic matter. It also showed high levels of mercury, lead, zinc and PCBs. Surface samples from this core and also PE-3 in the entrance channel have been designated as Class III. The remaining samples taken from the south cove and the entrance channel indicate lower pollutant levels in sandier sediments and are classified as I and II. This classification may be misleading as it is believed that sediment pollutant levels are generally higher, especially in fine sediments in northern portions of the Cove. The Corps of Engineers is resampling this area.
Bullock's Cove	3	-	3	-	1	2	6	Only four metals were analyzed by the Corps of Engineers for this area. Organic sediments from within the Cove at the north and south anchorages are high in most pollutants. Sources of these materials may be the Upper Providence River. Sandy sediments taken from the entrance and approach channels are significantly less polluted and can be considered Class I. This area exemplifies how one area having differing sediment types with differing pollutant levels can make good use of two or more disposal options.
Little Narragansett Bay	5	-	2	2	2	-	7	Two samples (PE-3 and PE-7) had high organic and water content and a moderately high hexane soluble fraction. PE-3, located in the channel west of Barn Island, Conn., also shows a class II mercury level in the surface layers. PE-7, just west of Pawcatuck Point nearer the mouth of the Pawcatuck River, showed slightly higher mercury levels and also class II chromium levels in the subsurface sediments. All other stations are considered class I including PE-4 situated midway between PE-3 and PE-7. In general, the ratio of metal levels to organic matter in the Bay sediments is low.
Greenwich Cove	-	-	2	-	2	-	2	These samples have high organic matter content, high water content, and pollutants, indicative of sewage rather than industrial sources. More samples are needed from this area.
Block Island New Harbor	4	-	1	N O	D A T A		5	Only surface samples were taken. They represent clean sandy sediments with low pollutant levels. The high mercury level in one sample (GE-2) is anomalous since the sample is low in all other pollutants.

TABLE 5 (cont.)

SUMMARY: APPLICATION OF A SPOIL CLASSIFICATION SCHEME TO EXISTING CORPS DATA ON SPOIL SOURCE AREAS

Location of Cores	Surface Sediment Classification			Subsurface Sediment Classification			Total # of Sample Stations	Discussion
Block Island Harbor of Refuge	4	-	-	NO DATA			4	Only surface samples were taken. Low silt/clay levels indicate that sediments are coarse grained and have low pollutant levels. All sediments considered Class I.
Brushneck Cove	1	4	4	1	8	-	9	The grain size and water content of all samples are similar. Four Samples having the highest water content and organic content have the highest hexane soluble fraction and metal content as well. Two of these four have lead and zinc levels slightly over the Connecticut standards for Class III. There is a marked decrease in all pollutants at a depth of 1 foot. Subsurface sediments all meet Class I criteria for metals but have been placed in Class II solely on the basis of a slightly elevated water content. Two of the four Class III surface samples (from PE-5 and PE-6) could also be upgraded to Class II if metal content alone is considered.
Apponaug Cove	2	-	4	1	2	1	6	Two types of sediment were found. Highly organic sediments had high hexane soluble fractions and mercury, lead, zinc, and chromium levels above the Connecticut Type III standards. Chromium in surface sediments in PE-1 and PE-2 (inner cove area) is the highest measured in any Rhode Island samples. Sediments below one foot depth met Class I standards for chromium, however. Low organic content, sandier sediments near the outer cove (PE-5, GE-6) have low pollutant concentrations.
Newport Harbor	1	1	1	1	-	-	3	One surface sample (PE-4) had high lead and zinc levels. However, the number of samples taken is insufficient for classifying these materials.
Wickford Cove	1	2	4	-	5	1	7	Surface sediments, particularly in inner cove, have high water content and high mercury levels and moderately high levels of lead, zinc and vanadium. Subsurface samples show a large decrease in lead, zinc and arsenic levels. Cadmium, nickel, and vanadium, however, show less of a reduction when compared to surface samples.
Warwick Cove	2	3	4	1	6	-	9	Several surface samples have high levels of mercury, lead, and zinc, high water content and a large amount of fines. All subsurface sediments have metal levels within Class I or II limits.
Pt. Judith Harbor	3	1	-	NO DATA			4	Data are taken from the 1976 EIS on Improvement Dredging of the Harbor Entrance and Channel Extensions near State Piers. Only four grab samples of surface sediments were analyzed. These samples may not be representative. Based on metal content only, three samples appear to be well within Connecticut Class I limits while one has been designated Class II because of somewhat higher cadmium levels.

It must be emphasized that while the Corps data on each site presented in Appendix A can be the foundation upon which to build a classification of Rhode Island dredge spoils, these data must be considered only as a starting point. Factors such as errors in the original sediment analysis or the taking of too few and too shallow cores or collecting them in sites unrepresentative of the area as a whole might lead to an incorrect conclusion. For example, the two samples from Pawtuxet Cove which fall into Class III on Table 5 are believed to be more representative of the Cove's entire surface sediments than the table would appear to indicate. The Corps of Engineers are undertaking additional core sampling in this area because of questions concerning the accuracy of these data and the location of the original cores. On the other hand, the Bullock's Cove cores are considered fairly accurate and are good examples of how sediments from different portions of an estuary can be segregated according to their pollutant levels and potential options for disposal.

Notwithstanding its shortcomings, the spoil classification approach can eliminate the need to perform expensive bio-assays on all sediment cores when they are relatively clean. The scheme can also point to specific areas where additional study is needed. Perhaps most important, since spoil classification can help to segregate areas according to contaminate levels, the scheme can serve to assure fishing interests that low-quality material having the potential to jeopardize fishing resources would not be disposed near fishing grounds. A spoil classification map for Rhode Island would probably show that much of the sediment in the Mount Hope Bay channel and in upper Narragansett Bay could be legitimately placed in Class I. Taunton River sediments would probably fall into Class III, due to high mercury levels. Pawtuxet Cove samples also would show as Class III on the basis of high water and organic matter content.

Many of the larger projects in Rhode Island will undoubtedly include materials in more than one class. Where there is lateral separation between sediment types they can be handled separately. For instance, it has been found that in Mount Hope Bay organic matter and most metals are correlated with distance from the Taunton River. However, zinc content and percent oil and grease are more widely distributed.

In addition to classifying spoil from dredging areas, spoil disposal areas need to be classified as to the types of spoil for which they are suited. This has been done informally in Massachusetts, where contaminated dredge spoils and chemical wastes are dumped in an area apart from that appropriate for cleaner material. Rhode Island should also classify its disposal areas according to bottom depth and the stability of the site, its historic usage, and economic factors such as transport and handling costs, hauling distances, etc.

IV. THE CONDITION OF SPOIL SOURCE AND DISPOSAL AREAS IN RHODE ISLAND WATERS

The potential effects that dredging and disposal activities may have on the marine environment are of considerable concern. This is particularly true in Rhode Island, where a significant percentage of the sediments are contaminated. Major concerns lie not so much with the areas to be dredged or used for disposal where severe disruption is unavoidable but rather with the potential effects to resources on the periphery of dredging and disposal locations. Many questions have been raised over the possible effects of dredging on commercial and sport fisheries, on shellfish beds in the shallows along our coastline, and on swimming beaches. The following discussions review the characteristics of spoil source areas in Rhode Island as well as the sites which have been used for spoils disposal. This review shows that while these activities are and will probably always be considered a necessary evil, they have not always had the negative consequences that many fear.

Pollutants in Spoil Source Areas

A knowledge of the levels and patterns of sediment pollutants in spoil source areas is important when selecting the disposal site and the dredging technique to be used. In many Rhode Island estuaries, polluting substances such as organic matter, fine-grained sediments, and hydrocarbons are common. In some areas, pollution levels are further increased by large point sources of a particular contaminant (such as mercury in the Taunton River). The following describes the major pollutants and their presence in Rhode Island marine sediments.

Hydrocarbons. Hydrocarbons may be toxic to marine life at high concentrations. At lower concentrations they may affect chemoreceptive mechanisms used in substrate choice, feeding, and reproduction. They can contribute to neoplasm (cancer-like) formation in bivalves, or cause tainting to the flavor of shellfish. In most polluted areas hydrocarbons are present in the water and are associated with suspended particles as well as sediments. Suspension-feeding organisms probably obtain most of their hydrocarbons from the water and not the sediments. Little is known about the uptake by shellfish of hydrocarbons in sediments in areas overlain by clean water. In a recent study of hydrocarbons in ocean quahogs near the Newport disposal area (Boehm and Quinn, 1977), no correlation was found between levels in the clams and the sediment. However, hydrocarbon levels in the sediments were found to be not unusually high. It is possible that if hydrocarbon sediment levels were higher, some uptake by the shellfish would have been observed.

TABLE 6

HEXANE-SOLUBLE FRACTION IN RHODE ISLAND MARINE SEDIMENTS (PARTS PER THOUSAND)
(Abstracted from Corps of Engineers, New England Division, Data)

Providence River	
Field's Point	2.73, 5.97*, 1.01
Pomham Rock	9.61*
Conimicut Point	2.11, 0.63, 0.88, 0.92, 0.35
Pawtuxet Cove	2.40, 1.63, 0.71, 7.09*, 0.10
Bullock's Cove	
Inner cove	1.60, 4.10, 11.70*
Approach channel	0.50, 0.40, 1.60
Warwick Cove	3.35, 2.25, 3.30, 0.69, 0.70, 3.55, 4.62 2.98, 4.06
Wickford Cove	2.22, 3.49, 2.14, 1.63, 2.91, 1.77, 0.22
Mount Hope Bay	
Upper (Mass.)	7.92*, 7.40*, 0.38, 0.56, 6.15*, 6.17*, 4.59 5.37*, 6.63*, 3.14, 4.56
Lower (R.I.)	1.23, 0.44, 0.29, 1.5, 1.75, 0.83, 0.98 1.28, 0.30, 0.91, 2.0, 0.96
Rhode Island Sound	
Brown's Ledge	0.70, 1.29, 0.85, 0.74, 1.56. 0.58, 0.43 0.07, 0.43, 0.12, 0.26, 0.12, 0.36, 0.40 0.53, 0.36, 0.48, 0.0, 0.24, 0.20

*Hydrocarbon levels in these cores exceed the 5 ppt standards for Class I determined by the Connecticut classification scheme.

Two techniques for measuring hydrocarbon levels are in common use. Oil and grease content is determined by a hexane-extraction process used by the Corps of Engineers. University of Rhode Island researchers use a similar extraction system but follow this with a process to separate petroleum hydrocarbons from the waxes and oils which are found in natural organic matter. The final values of the techniques used by the Corps and the University of Rhode Island are similar, but while petroleum hydrocarbon levels decrease offshore, levels of "oil and grease" determined by hexane extraction remain as high as those found in some inshore sediments because natural materials are being included. Table 6 shows Corps hexane-soluble fraction levels taken from sediment cores throughout Rhode Island. Cores showing greater than 5.0 ppt (parts per thousand) are considered high. High concentrations are found at Field's Point, Pawtuxet Cove, Bullock's Cove, and upper Mount Hope Bay.

The primary sources of hydrocarbons in upper Narragansett Bay include small spills of industrial fuel oil and sewage treatment plant effluents. The Field's Point plant is an especially significant source. University of Rhode Island data shows a general hydrocarbon distribution trend from high levels near Field's Point to low levels on sand bottom in Rhode Island Sound. There is also a rapid decrease in hydrocarbon concentration below a depth of 20-40 cm in the sediment in most of the Bay. An exception is an area east of Prudence Island, where concentration increases with depth for unknown reasons. This accumulation of hydrocarbons in near-surface sediments (similar patterns are found for metals) reflects the large increases in Narragansett Bay pollutants within the last century. Table 7 shows the results of several University of Rhode Island studies involving hydrocarbon concentrations.

The standard for classifying levels of hydrocarbons defined by the state of Connecticut as "non-degrading" is 5 ppt hexane-soluble fraction. As shown in Table 6, many of the dredging source areas in Rhode Island have surface values this high. Horizontal and vertical partitioning of spoils during dredging and burial techniques at offshore sites should be used where possible to reduce the exposure of these hydrocarbon-contaminated sediments.

<u>PCBs and pesticides</u>. Polychlorinated biphenyls (PCBs) have been used in a variety of products, and they are found in low concentrations in land runoff and sewage effluents. These compounds have been found to be similar to chlorinated pesticides in toxicity, long life, and potential for bio-accumulation. Very high levels have resulted from the disposal of large quantities of PCBs in some waterways. PCB dumping in New Bedford, Massachusetts, for example, has resulted in sediment levels several orders of magnitude greater than those in Rhode Island.

TABLE 7

HYDROCARBON LEVELS (IN PARTS PER THOUSAND) IN RHODE ISLAND MARINE SEDIMENTS

(Abstracted Data from University of Rhode Island Studies)

Van Vleet and Quinn (1977) Providence River and Upper Narragansett Bay

Station Designation	0-10	10-20	20-30	30-40	Depth below sediment surface (cm)
1. Upper Harbor	1.41	1.23	0.54	0.52	
2. Field's Point	5.41	4.56	4.46	1.48	
3. Gaspee Point	0.45	0.51	0.33	0.02	
4. Conimicut Point	0.57	0.47	0.02	0.02	

Farrington and Quinn (1973) Narragansett Bay

Station Designation		Average	Range
FP	Field's Point	2.11	0.82-3.56
E_1	Sabin Point	2.04	0.50-5.70
E_2	Upper Bay	0.71	0.46-1.07
D	Hope Island	0.40	0.35-0.44
C	Fox Island	0.15	0.13-0.16
B	Jamestown Bridge	0.15	---
A	Dutch Island	0.11	0.10-0.12
WR	Whale Rock	0.06	0.05-0.06

Hurtt (1978) Narragansett Bay

Station Designation		Total Hydrocarbons
5	North of Prudence Island	.509
6	West of Patience Island	.359
7	North of Hope Island	.356
8	South of Quonset Point	.246

TABLE 7

Hurtt (1978) Narragansett Bay (cont.)

Station Designation	Total Hydrocarbons*
9 East of Rome Point	.0292
10 Near Jamestown Bridge	.0451
11 West of Beavertail	.0721
12 West of Fort Adams	.0346
13 Near Newport Bridge	.0688
14 North of Gould Island	.283
15 South of Prudence Island	.112
16 East of Sandy Point, Prudence	.333
17 East of Homestead, Prudence	.373
18 Southwest of Hog Island	.361
19 Southwest of Hog Island	.361
20 West of Poppasquash Point	.505
GB Greenwich Bay	.454
L Near Sauga Point	.0632
S Off Northwest Jamestown	.0713
N South of Fort Wetherill	.0405

Station 17	
0-5 cm	.373
5-10 cm	.325
10-15 cm	.445
15-20 cm	1.650
20-25 cm	1.108
25-30 cm	.117

*Data listed are from 0-5 cm depth in a sediment core. Stations 18 and 19 show slight increases in hydrocarbon levels with depth. The large increase shown in Station 17 is indicative of a past source of petroleum pollution. All other stations show decreasing levels with depth.

Boehm and Quinn (1977) In and around Brenton Reef Dump Site

Station Designation	Total Hydrocarbons	
40 Silty sand	.056	Outside dump
43 Silty sand	.027	Outside dump
50 Silty sand	.051	Outside dump
30 Silty sand	.029	Outside dump
18 Silty sand	.0229	Outside dump
31 Sand	.0076	Outside dump

TABLE 7

Boehm and Quinn (1977) In and around Brenton Reef Dump Site (cont.)

Station Designation	Total Hydrocarbons	
46 Sand	.0139	Outside dump
44 Sand	.0208	Outside dump
45 Sand	.0468	Outside dump
22 Sand	---	Outside dump
21 Sand	.0010	Outside dump
20 Sand	.0040	Outside dump
17 Dredge spoil	.0439	At dumping area
16 Dredge spoil	.0962	At dumping area
15 Dredge spoil	.0461	At dumping area
19 Dredge spoil	.0211	At dumping area
8 Dredge spoil	.0210	At dumping area
9 Dredge spoil	.104	At dumping area
4 Dredge spoil	.301	At dumping area
3 Dredge spoil	.053	At dumping area
2 Dredge spoil	.116	At dumping area
1 Dredge spoil surface	.0184	At dumping area
1 Dredge spoil subsurface	.184	At dumping area

In Rhode Island, the highest PCB levels found were 3.8 and 1.8 ppm in highly organic sediment in Pawtuxet Cove and near Field's Point. Typical levels in Narragansett Bay are less than 0.11 ppm and less than 0.01 ppm in Rhode Island Sound. There is some evidence that levels decrease with depth in the sediment in all areas.

PCBs are not seen as a special problem in sediment pollution in Rhode Island (Paulson and Brown, 1978). The sediments in which they are moderately high are also polluted with other substances. PCBs, like pesticides, are strongly bound to fine-grained sediments and particulate organic matter, and thus can be successfully contained.

Chlorinated pesticides do not reach high levels in Rhode Island marine sediments and do not have to be considered as a separate problem.

Heavy metals. Contamination of dredged materials by metals has been a major concern in Rhode Island. Reasons for this include: 1) the possibility of metals entering the Bay from metal-working industries with inadequate waste-treatment facilities; 2) the high toxicity of metals shown through laboratory bioassays; and 3) the organo-mercury compounds that have been observed to accumulate in most aquatic organisms and the several metals accumulated by bivalve mollusks. Metals have also been suggested as possible tracers of eroding dredged materials.

A report in preparation by the Coastal Resources Center will examine metal inputs, levels in water and sediment, and water-sediment transfer mechanisms in Narragansett Bay. A literature review made for that report suggests that of all the metals in the Bay dissolved copper most closely approaches levels found to be toxic in laboratory tests (J. Gallagher, personal communication).

Recent field studies by Phelps and Myers (1977) showed elevated levels of cadmium, lead, nickel, and copper in hard clams from the upper Bay. Studies with caged mussels by Phelps and Galloway (unpublished) show rapid uptake of lead, nickel, and copper in the upper Bay. This demonstrates that suspension feeders acquire metals from the water column in dissolved form or on food particles. The degree of uptake by infauna of metals within sediments, however, is very questionable. It may also be quite complex as well. Of interest is a recent finding which indicated that one species, a polychaete worm, took up metals only when under salinity stress (Jones et al., 1976). Despite these ambiguities, sediment metal levels can be used to show the general level of pollution and to pinpoint cases of gross contamination.

A large number of metal analyses have been carried out in Rhode Island by the Corps of Engineers. The results of these analyses are presented in the Appendix. Connecticut sediment standards are also listed to show the relative levels of pollution. Highest metal levels occur in the Providence River and Pawtuxet Cove. Zinc, copper, and lead are particularly high in sediments, which also contain high levels of organic matter; this indicates that they originate in sewage effluents. Sediments in other Rhode Island harbors and in the Rhode Island portion of Mount Hope Bay show moderate metal levels, with the exception of relatively high mercury levels in some samples from Wickford, Bullock's, and Greenwich Coves. In the more polluted areas there is a marked decrease in metals from the sediment surface to a depth of one foot.

The Fall River dredging EIS discusses mercury contamination in the Taunton River which resulted from long-term discharge from one industrial plant. Mercury levels from this source decrease rapidly south of the Braga Bridge (Corps of Engineers, 1976). Different disposal options for sediment from north and south of this area could be used.

A manufacturing plant on the Pawcatuck River has been a point source of metals. High copper and zinc levels may require containment of dredged material from this area.

Pathogenic microorganisms. Since most dredge spoil source areas are in SB and SC waters (restricted shellfish areas), it must be assumed that pathogenic bacteria and viruses are present in the sediments as well as in the overlying waters. The Food and Drug Administration (FDA), Northeast Technical Services Unit, is responsible for monitoring bacterial contamination in mollusks in Rhode Island Sound and for closing areas to mollusk fishing. The criteria used for closing an area to shellfishing include evidence of sediment movement at the disposal site, the results of tests for pollution indicating bacteria in clams, and the presence of specific organic compounds in the sediment. The minimum size of a closure area is one mile in diameter. The FDA shellfish safety standards are designed for species that are eaten raw or partially cooked. These standards provide a large safety factor for ocean quahogs, which are always well cooked before they are eaten.

Oxygen demand. During the decomposition of organic matter found in estuarine sediments, hydrogen sulfide and reduced organic compounds are formed. When these substances are released into the water column, a drop in dissolved oxygen results. Dissolved oxygen levels may be dramatically lowered during the dredging and disposal operation in confined areas. The large decrease in oxygen can place stress on organisms.

Burial of bottom organisms by anoxic sediments may decrease their chances of reaching the surface following spoil disposal. Anoxic sediments also may contribute to reduced survival of larval invertebrates if they settle on recently deposited material.

Sediment fluidity. An important consideration in evaluating the disposal options for fine-grained sediments is their cohesiveness. While improvement dredging often involves large volumes of cohesive sediments with large particle size and low water content, much of the proposed maintenance dredging in Rhode Island involves sediments with high water content (80-90 percent in Pawtuxet Cove) and a high percentage of silt-sized and low-density organic particles. These latter sediments may be extremely fluid and flow along the bottom after being dumped from a scow and thus assume a very low angle of repose. They will, therefore, require a relatively large disposal area if no containment structures are used. They will also be more subject to erosion than clays or mixed sediments. Fine-grained incohesive sediments also tend to be slow to dewater when containment is used.

Condition of Subaqueous Disposal Sites in Narragansett Bay

In the past, dredged materials from small-scale projects were frequently dumped on salt marshes or in shallow waters close to shore. Materials from larger projects undertaken prior to 1967 were usually dumped in deeper open waters within the Bay. The major disposal site was southeast of Prudence Island, in depths over 100 feet. Also, at Quonset/Davisville, the Navy dumped materials into the West Passage as part of channel dredging in addition to the large volumes that were pumped onto land. In Mount Hope Bay, spoil has been deposited in deep portions of the channel and in shallow waters adjacent to Spar Island.

Spoils disposal within the Bay was largely discontinued in 1967 with the selection of Brenton Reef in Rhode Island Sound as a dump site for the Providence channel project. The Bay was used once since then; in 1975 approximately 50,000 cubic yards of hardpan and boulders from the Providence River were deposited in a deep hole in the channel south of Conimicut Point.

There have been few post-dumping studies of mid-Bay disposal areas. In order to see whether the degree of spoil erosion and colonization by benthic animals could be assessed, grab samples of three Bay disposal areas were taken in spring of 1978 as part of this study.

Quonset/Davisville. A subbottom profile made by Collins (1977) of some small elevated areas east of the Davisville piers shows that they consist of hydraulically dredged sediment up to ten feet thick (see Figure 3). Sediment sampled (in 1978) at 20-foot depths adjacent to the mounds were naturally occurring silty sands. A sample at a depth of approximately 15 feet was medium sand with a small silt component and some fine worm tubes indicating periodic, but not continuous, winnowing of fine material. Since the spoil was deposited 36 years ago and the slopes are very gentle, the mound has probably reached a stable form. The area around the dredged channels and turning basin is avoided by trawlers because of the possibility of snags. The area adjacent to the spoil mounds has been mapped as productive quahog ground (Coastal Resources Center, 1977) for dredge boats, although quahog harvesting by dredging has not been allowed in Narragansett Bay for several years. It can be concluded that little sediment migration is taking place at the spoil mound at present and that the spoil mound has been colonized by benthic animals.

Conimicut Point. Dredging of the main shipping channel and disposal within a deep hole south of Conimicut Point was monitored by the University of Rhode Island during 1975 by Pratt and Bisagni (1976). Turbidity was found to be minimal around the working bucket dredge. When the spoil was dumped, suspended sediment was carried with the current, but remained in the channel and below the thermocline, which was well developed in the summer. Sport fishing took place near the dump site during disposal activities.

In 1975, grab samples and scuba dives at the disposal site produced a variety of sediments varying from fine silt to sand. Because of the narrowness of the channel, it seemed possible that the deep hole was an area of erosion for fine sediments. Samples taken in 1978 included cohesive silt with shells and pebble, together with sand, indicating that some erosion of fines takes place and that it is not a suitable area for dumping fine-grained incohesive sediments.

Prudence Island. At least 1,500,000 cubic yards of spoil was dumped in a large area over 100 feet deep between Prudence and Dyer Islands between 1949 and 1966. No sediment samples, subbottom records, or side scan records have been found which would show the presence of spoil in this area.

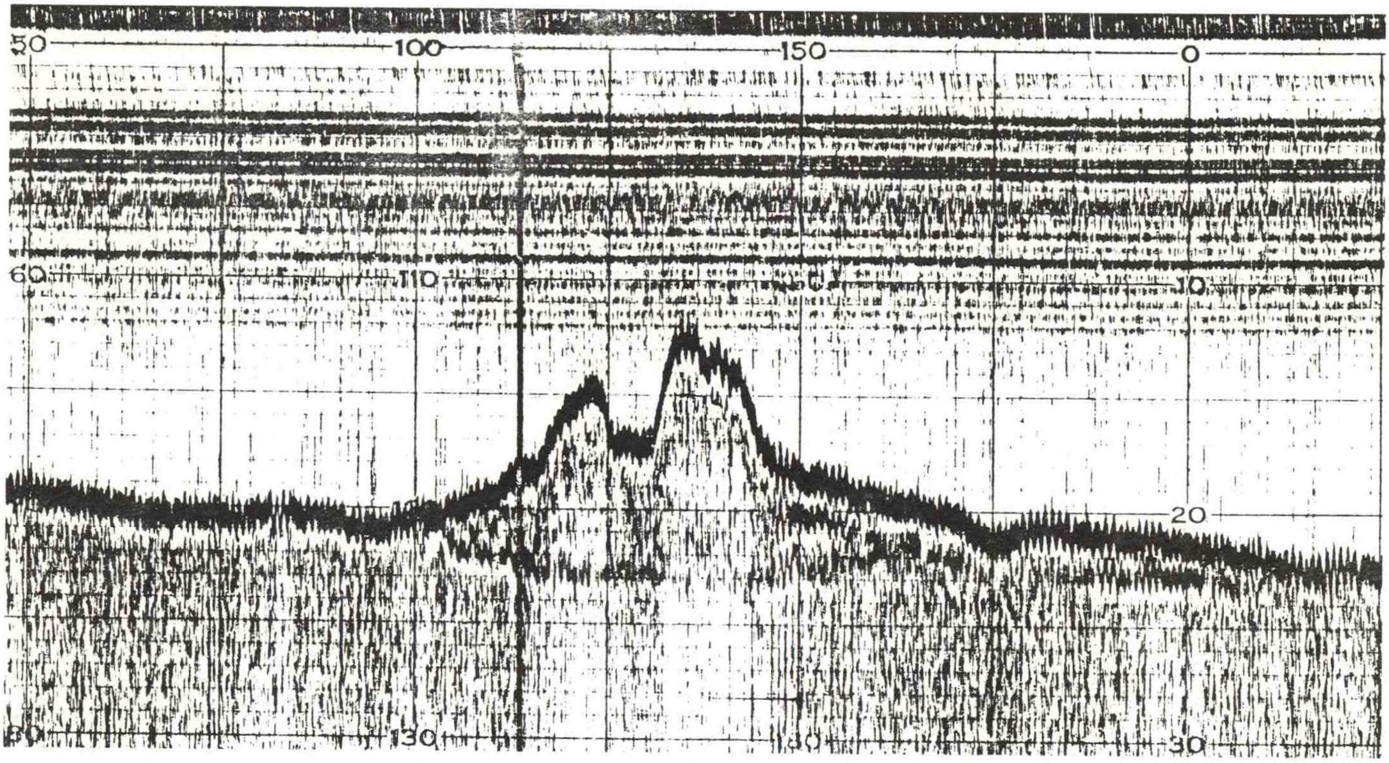


Figure 3. Subbottom profile of dredged material on estuarine sediments near Davisville, Rhode Island. Vertical exaggeration approximately 64:1. The ten-foot-high spoil mound extends about 2500 feet. (7.5 KH profile taken by B. P. Collins, May 1977)

Three grabs taken in March 1978 yielded one silty sand sample and two soft silty samples containing a large population of a small bivalve (Nucula proxima) characteristic of the muddier areas of the Bay. One grab had a deposit of small shells in the surface indicating weak erosion. Although three samples provide only a very rough indication of the condition of this site, they do suggest that the area has good containment properties and that spoils dumped in the past are being buried by present sedimentation processes.

It is not known to what extent this area is used for trawl fisheries. The present fisheries in this general area include trawling south of Prudence Island, mussel dredging on gravelly bottoms near Dyer Island, and sport fishing from boats and the Melville shore. The large volume of water passing through this area suggests that suspended and dissolved pollutants introduced here would be greatly diluted and probably widely distributed.

The data available on the status of these mid-Bay disposal grounds are certainly much too scanty to permit sound conclusions to be drawn. However, what we do have gives no cause for alarm. It would be desirable to document further the location of spoils and the effects of dumping in the past, particularly on the resources in the vicinity of the Prudence Island site.

Conditions at Brenton Reef

A site four miles seaward of Newport was used for the disposal of 10,000,000 cubic yards of dredged material between 1967 and 1971. Most of the spoils came from improvement dredging in the channel to Providence. The only other sediment sources were Brayton Point in Mount Hope Bay and the entrance channel to Point Judith Harbor. The site is still being actively studied by the Corps of Engineers and the Narragansett EPA laboratory to determine the effects of disposal on the site, to make projections on the effects of renewed use of the area, and to assess the impacts of disposal at other sites in Rhode Island Sound.

Dredged material disposition and erosion. The greatest volume of spoils at Brenton Reef is in a broad mound near the west corner of the disposal area. Spoils can be found shoreward of the site which were caused by spillage (and by what is thought by some to be intentional "short" dumping) from scows approaching and leaving the area. Spoils can also be found southwest of the site at areas that were used temporarily in 1967.

The principal spoil mound has been mapped several times by the University of Rhode Island and will be mapped with greater accuracy by the Naval Underwater Systems Center (NUSC), Newport, twice a year for at least five years, beginning in 1977. The only change detected by previous mapping is a loss of up to two feet from the shallowest portion of the spoil mound.

Grab samples and examination by divers provided further evidence that erosion has taken place on the top of the spoil mound. At depths of less than 90 or 95 feet, a layer of shelly sand a few inches thick overlays cohesive spoil sediments. A rapid transition to soft silt takes place at 95 to 100 feet. In October 1977, NUSC made side scan sonar records of the site (NUSC and Army Corps of Engineers, 1977). Ripples facing east-west with a wavelength of 1.1 meters could be seen at depths of less than 95 feet.

The rate of erosion on the mound and the site of redeposition of the eroded spoils has not been determined. Research on the problem, however, continues. A URI Ocean Engineering/EPA study is modeling the effects of waves on the spoil mounds, and EPA has developed methods to identify coarse-grained spoil-derived sediments beyond the mound by grain types and shape and by the identification of foraminifera. Attempts have been made to map the deposition of fine-grained spoil in Rhode Island Sound through higher than normal levels of metals such as chromium (R. Payne, personal communication). During 1978, NUSC will be carrying out additional bottom current measurements and bottom turbulence experiments at the site, which should give further insight to sediment movements.

Recolonization by bottom invertebrates. The populations of invertebrates occupying the spoil-affected area are of interest because they have value as fish food and act as indicators of the extent to which the environment deviates from "normal" conditions.

The disposal area is on stable sand bottom. Rippled sand is found at shallower depths to the north and east and silty bottom is found to the west. The bottom animals which existed before disposal began probably included high densities of tube-building amphipod crustaceans, ocean quahogs, deep burrowing mud shrimp, cancer crabs, and a large number of tube-dwelling and free burrowing polychaetes and crustaceans.

A dense and diverse amphipod-dominated community is found close to the site in the easterly direction. Spoil does not extend beyond the dump site boundaries in that direction, but fine sediments, released during the disposal operations and by later erosion, must have settled in this area. It appears that these sediments have been incorporated into the natural bottom by animal activities without causing changes in the natural community.

While dumping was still taking place in 1970, a large number of species from adjacent areas were found on recently deposited spoil, although densities were low. On the basis of these initial data, a theoretical model was developed predicting the time for complete repopulation. The predicted colonization was not completed, however, because of the sediment differentiation which took place on the mound. The shallowest portions now covered by rippled shelly sand have low densities of species specialized for such habitats. In deeper areas, fine-grained sediments are occupied by species found on muddy bottoms in Rhode Island Sound and in the deeper parts of Narragansett Bay. Muddy bottoms support fewer species of importance as food for fish than does the stable sand bottom natural to this area. However, winter flounder and scup may benefit from a change toward a muddier bottom. To a large extent, the disposal site at Brenton Reef has been recolonized, with few sections totally devoid of invertebrates. However, the production of commercially valuable species has been reduced.

Pollutant levels in sediments. Dredging of the Providence Channel was carried out in a north to south direction. As a result, the most contaminated sediments from Providence Harbor were buried by relatively clean sediments from upper Narragansett Bay. Sediments recovered on the surface of the Brenton Reef spoil mound in 1972 by URI and in 1975 by EPA (Narragansett) have pollutant levels typical of the upper Bay and are in the "non-degrading" category, as defined by the Connecticut dredging plan. The following ranges of pollutants have been found in source areas, at the dump site, and at a clean offshore area by the Corps of Engineers.

	Appendix A this report	Appendix A this report	Pratt, Saila, Sissenwine 1973	Fall River EIS - R.I. Sound
	Upper Prov. River	Conimicut Point	Brenton Reef dump site	Brown's Ledge
Number of samples	(7)	(4)	(33)	(37)
Oil/grease (ppt)	1.01-2.73	.35-2.11	.12-1.0	.07-1.56
Mercury (ppm)	0.38-1.82	0.03-0.44	0.06-0.29	0.0-0.08
Zinc (ppm)	376-1,379	33-177	16-89	10-89
Lead (ppm)	131-836	12-109	10-43	9.41

Chromium appears to be a useful tracer of spoil sediments, since it is high in upper Bay sediments and low offshore. It is "primarily associated with the particulate inert system and does not appear in the biological system beyond the secondary consumer level in the food web" (Phelps et al., 1975). EPA (Narragansett) has analyzed chromium from sediments throughout Rhode Island Sound. Although the results have not been released, it appears that increases due to spoil disposal were detectable southwest and northwest of the Brenton Reef site to a maximum distance of two miles (R. Payne, personal communication). Sources of chromium in these areas include dumping at the temporary site, spillage on route to the site, and deposition of fine material suspended during dumping or eroded from the spoil mound.

Boehm and Quinn (1977) were able to distinguish dredged material from the surrounding natural sediments on the basis of qualitative and quantitative hydrocarbon distributions. The highest levels measured were similar to Van Vleet and Quinn's (1977) results for upper Narragansett Bay (Table 7). Corps of Engineers analyses are less sensitive to hydrocarbons, and there is little difference between levels in the spoil at Brenton Reef and natural levels at Brown's Ledge (Tables 6 and 7).

Since most pollutants of concern at the disposal site are strongly associated with fine-grained sediments deposited early in the project, environmental effects will be minimized as long as they remain buried. Future sampling to detect a correlation between pollutants in sediment and bottom animals should be carried out at the temporary dump sites to the southwest of Brenton Reef, where upper Providence River sediments may be more exposed.

Pollutants in animals. A number of tests have been made to identify pollutants in ocean quahogs (*Arctica*) taken in the vicinity of the disposal site. Hydrocarbons were measured in surface sediments, sediment cores, and ocean quahogs by Boehm and Quinn (1977). They found "no systematic variation in *Arctica's* hydrocarbon concentration with distance from the dredge spoil site." They also found that the hydrocarbon levels were low and relatively constant. It appears that the exposure to petroleum in sediments, in suspension, and in water-accommodated form was low. Bivalves which are exposed to high chronic levels take up hydrocarbons and retain them even after transfer to clean water (Boehm and Quinn, 1977). There was no noticeable effect on the taste of ocean quahogs taken from the area by EPA (Narragansett) in 1975 (R. Payne, personal communication).

Bacteriological analyses were made on ocean quahogs collected at three stations within a half mile of the disposal area in December 1976 by the FDA, Northeast Technical Services Unit, Davisville, Rhode Island. These specimens are free of indicator bacteria. This result is consistent with results of investigations reviewed in the Fall River EIS on survival of bacteria in the marine environment and with the results of Birely and Buck (1976), who studied a disposal site off New Haven.

Histopathological studies have been made of ocean quahogs from Rhode Island Sound by EPA (Narragansett). The results of these studies have not yet been released. The kidneys of ocean quahogs are being studied because the kidneys of Bay quahogs in the Providence River have been found to contain dark concretions. Informal investigations by the University of Rhode Island indicate that all ocean quahogs have solids including both concretions and mineral crystals in their renal sacs, that the oldest animals have the most material, and that there is no obvious relationship with proximity to the disposal area. The kidney is much less conspicuous than the stomach and digestive gland. It is possible that early reports of enlarged kidneys in ocean quahogs referred to the stomachs of actively feeding animals.

Metals have been measured in ocean quahogs throughout Rhode Island Sound by EPA (Narragansett), but the data have not been released. Quahogs sampled from the disposal site area in December 1975 have been analyzed by the FDA. The results are shown in Table 8. Calibration samples from Rhode Island Sound (EPA) and samples from Block Island Sound (NMFS) show natural levels which can be used as reference. Also given are levels in Bay quahogs which, according to the FDA, warrant the taking of some restrictive action. The slightly higher levels found in the disposal site animals are well within the error to be expected from the different techniques used by the various laboratories.

Fisheries

Floating trap fishery. Of all the resources which could be potentially affected by spoil disposal at the Newport site, the trap fishery is the most difficult to assess. The major trap fisheries in Rhode Island are located off Newport and Sakonnet within three to four miles of the disposal site. The major target species is scup. Scup catches were very large in 1964 and 1965, and declined steadily during the period when spoil was being deposited. It was argued by fishing interests that suspended sediment from eroding spoil had caused the scup to change their migratory paths.

TABLE 8

METAL CONTENT OF OCEAN QUAHOGS

(PPM WET WEIGHT)

	Hg.	Cd.	Zn.	Cu.	Pb.	Cr.
Newport disposal area (FDA, 1977)	ND	0.24	36	3.2	1.10	1.5
	ND	0.28	40	3.2	1.20	2.1
	ND	0.22	36	4.0	1.40	2.0
	ND	0.24	20	3.0	0.96	1.6
	ND	3.20	16	3.2	1.40	1.8
R.I. Sound calibration sample (EPA, Narragansett)	--	0.17	17.3	2.82	1.27	1.0
Block Island Sound* (NMFS, 1975)	0.05	0.21	21.9	3.7	2.15	--
FDA action level (hard clams)	--	0.5	65	10	--	--

*Dry weight converted to wet weight by dividing by 8.35

Sissenwine and Saila (1974) analyzed trends in the scup fishery and showed that a decline in scup catches had occurred in various areas from Rhode Island to Virginia between 1958 and 1963. Scup recovered in all areas in 1975 and 1976, making it clear that the decline in Rhode Island catches was part of a regional trend.

The problem is not completely resolved, however, since there is evidence that erosion of the surface of the spoil pile has taken place and, furthermore, little is known about the behavior of schools of fish in natural environments. Preliminary experiments by Marchesseault and Saila (1977) indicate that scup move away from areas of falling fine sand in test tanks. Wilson and Connor (1976) found that visually acute fish such as mackerel would enter and feed in water made opaque by china clay discharges, but that shoals of "whitebait" (small herrings) were observed to avoid the edge of "dense-white" water. There is no reason to think that scup are unusually sensitive to suspended sediment, since they enter turbid estuaries and feed on the bottom.

<u>Other commercial finfisheries</u>. The pattern of fishing around the dump site has changed over the last eight years, both because of the dumping activity and changes in gear use.

Previous to dumping, scup and butterfish were caught in the summer by small vessels from Newport. This fishery is no longer active because of obstructions in the dump site and because of a large increase in the number of lobster pots in the area. In the past, large cod catches were taken by trawlers as the cod fed on quahogs broken by dredges. Winter cod catches east of the dump site have varied in size from year to year but do not seem to be related to the presence of dredge spoils. The major bottom fishery close to the disposal area is for ocean pout in the winter by trawlers from Point Judith. A typical tow path starts several miles southwest of the disposal site and runs northwest, coming within a mile of the southern corner, then turns north to the vicinity of the 90-foot contour. This course avoids spoil at the temporary sites southwest of the site and a wreck south of the site. As many as ten vessels participate in this fishery.

Midwater pair trawling for the blueback herring is carried out shoreward of the disposal site during the winter in years when the fish are abundant. Herring were not caught in 1978.

Tub trawls (with long lines of baited hooks) have traditionally been used to catch cod along the 90-foot contour northeast of the dump site. The gear is used in the winter by lobster boats. Gill nets can be used by the same-size boats and are much more productive. In 1978, gill netting was successful both on, and adjacent to, the disposal area.

Sport fishing. There is no interaction between sport fisheries and the Newport dump site. The nearest sport fishing area is around the Brenton Reef Tower, a location which is considerably more turbid than the dump site, due to its closeness to Narragansett Bay and the soft bottom at the mouth of the Bay.

In general, sport fisheries are less likely to be impacted by the presence of a spoil mound than commercial trawlers because a smooth bottom is not required by sport fisheries. An example of absence of effects of dredge spoils on sport fisheries was the good catches of bluefish made adjacent to an active dredging and disposal operation at Conimicut Point in 1976.

Ocean quahog fishery. The impact on the ocean quahog fishery at the Newport dump site was severe and direct. A large population of clams was buried, and fishing had to be curtailed around the edges of the area because some clams were moribund or had foul-smelling mud on their shells. The greatest problem occurred southwest of the site, where highly polluted spoil from Providence Harbor was deposited at two temporary sites (see Section V, Figure 4).

From 1967 to 1970 there was no procedure for closing the area to clamming. The FDA Shellfish Sanitation Branch now takes an active role in monitoring and determining fishing closures in Rhode Island Sound and will close an area no smaller than one mile in diameter if sediment from polluted areas is being dumped. In the past, the processors of ocean quahogs asked that fishermen avoid the disposal area.

Between 1970 and the present, ocean quahog fishermen have switched from "rocking chair" dredges to hydraulic dredges. More fishing is now done in sandy sediments, which yield a higher quality product. Recently, fishing has been carried out north and northeast of the disposal site at depths of less than 90 feet.

Lobster fishing. Previous to the establishment of the disposal site, lobstering had been limited somewhat by the activities of trawlers. Some lobstermen avoided the area while dredged materials were being dumped, but others fished within the designated site. Lobstermen who did fish the site had several problems which included having to avoid the towboat path, the sinking of small pots into the sediments over several days' time, and, on one occasion, entangling pots on a heavy cable.

One fisherman reported high catches immediately after dumping ended, while another reported a recovery period of a year or two. In 1976, six lobstermen using the area were interviewed. Moderate catches were reported consisting of a small number of resident lobsters and a larger number of lobsters moving offshore in July and August. Catches have been similar in subsequent years. The condition of the lobsters was better than in areas that are heavily used by trawlers. Large numbers of crabs have been caught on the west and south edges of the spoil mound.

The men working in this area find it as good or better than areas of undisturbed bottom, and find that preemption of the area by lobstermen has increased their fishable area. Some lobstermen may have less positive feelings about the spoil area, but they have not been identified.

Conclusions

It has been determined that moderate erosion and resuspension of dredge spoil sediments has occurred at the Brenton Reef dump site. Due to the depths at the site, erosion probably occurs primarily during periods of high wave energies associated with severe storms. Although Brenton Reef has undergone considerable study and monitoring since the last major disposal activity in 1971, the degree and rate of sediment erosion remain unknown and should be determined. It is known, however, that the vast majority of the spoils are still at the site.

Inaccurate dumping resulted in a larger area than necessary being used for disposal. This problem should be corrected in any future disposal actions.

It has also been determined that benthic colonization has occurred on the site and that levels of metals, hydrocarbons, or other polluting substances are low in exposed sediments. Proof of the effects of contaminants has been difficult to find. Although species composition differs somewhat from the original community, the suspected cause is the difference in sediment type rather than specific chemical components of that sediment.

The use of Brenton Reef as a dump site has altered fishing activities and patterns considerably. This is due largely to the effects of changes in topography and sediment type on fishing gear (dragging and lobstering) and to a lesser extent to burial and the possibility of contamination to ocean quahogs in the immediate dump area. Fishery values for commercial clam and finfishing have decreased, while lobster fishing has improved. The overall amount of fishing in the area has probably not been decreased by the dumping of spoil.

Similarly, few deleterious effects have been identified from past disposal at subaqueous sites within Narragansett Bay. However, this may be due to a lack of documentation. More information should be obtained on the degree of sediment erosion (and the potential of its transport back into channels), colonization, containment levels, and long-term changes to fishing activities directly related to spoil disposal in mid-Bay waters.

V. OPTIONS FOR DREDGED MATERIAL DISPOSAL

Requirements and Summary of Options

In order that proposed dredge and disposal activities be made acceptable in today's political and social environment, several basic steps should be taken. It has become apparent that the failure to accommodate these elements in the planning and implementation process in the past has jeopardized the success of future projects or caused significant public concern.

1. Accurate cost/benefit determinations must be made prior to any action which demonstrate that the dredging project is economically justifiable.

2. Disposal sites should be chosen which are environmentally suitable, where disposal will have little impact on fishing areas, recreational beaches, and other economically valuable resource areas.

3. Major disposal projects or those involving a new or innovative technique should be accompanied by an adequately designed and implemented monitoring program. Until recently, monitoring of disposal areas after dumping was rarely undertaken, and when it was, it was done in an unsystematic fashion.

4. In all onshore or nearshore disposal programs, municipal agencies should be included in the planning process.

5. Rhode Island should change its attitude about dredge spoil. Instead of considering it as something to get rid of quickly, we should be looking at the potential resource values of this material and how it might be utilized to our advantage. This is the philosophy that other parts of the country have already adopted.

The recently approved Coastal Resources Management Plan has established a policy which recognizes that ocean dumping is presently the most efficient means to dispose of large amounts of dredged materials. However, the Plan also advocates the use of alternative and innovative solutions to the disposal problem (CRMC, 1978).

The major options for disposal of spoils in Rhode Island are as follows:

1. offshore disposal in deep water in the Sound;

2. disposal in deep water of the Bay;

3. development of a large containerized island in Mount Hope Bay;

4. enlargement of existing islands;

5. creation or enlargement of coastal wetlands (primarily salt marsh);

6. buildup or extension of commercial waterfront;

7. beach restoration;

8. aquatic habitat development;

9. upland uses (sanitary landfill cover, land reclamation, agriculture, etc.).

Most of these options will be examined in detail below, with the exceptions of aquatic habitat development and upland uses. The creation of usable recreational shellfishing habitat in Rhode Island may have less potential than salt marshes due to the large amount of contaminated sediments and the scarcity of suitable sites. Disposal in upland areas for sanitary landfill cover, land reclamation (gravel banks or other mined areas), and agriculture may become important in the future if studies by the Corps of Engineers and others adequately solve questions of water quality and health hazards.

It must be recognized at the outset that in Rhode Island many of the options listed above are likely to be useful only for small-scale dredging projects and will not produce a long-term solution to the spoil disposal problem. The amount of maintenance dredging presently needed would produce nearly three million cubic yards of materials. This and the limited number of potentially suitable marsh or island sites in Rhode Island emphasize the need for finding appropriate disposal grounds capable of handling large volumes over a long period of time. These could be either large subaqueous disposal grounds offshore in the Sounds or possibly a large containerized or otherwise stabilized island in an acceptable location inshore. It is urgent that efforts continue on a state and regional level to select an economically and environmentally acceptable disposal site for such large projects as those that have been proposed for the Providence River and Mount Hope Bay. In this regard, consideration should be given not only to Brown's Ledge and similar areas in the Sounds, but also to existing dump sites at Brenton Reef and South Prudence, each of which could accommodate more spoil. For a large number of smaller-scale projects, however, it is possible that other methods of spoil disposal can significantly replace or supplement traditional methods.

Potential Small-Scale Solutions

Salt marsh building. Two dredged material disposal options receiving wide study and recognition in many parts of the country are the building of salt marshes and islands. Undertaken primarily as research projects which studied the feasibility of utilizing various types of dredged materials for productive purposes, several marshes, islands, and aquatic habitats have been built or expanded along the southeast coast and in the Pacific northwest. These projects were initiated in 1973 by the Corps of Engineers at the Waterways Experiment Station in Vicksburg, Mississippi, as part of its Dredged Material Research Program (DMRP). One project has been undertaken in the New England area, which involved the successful creation of an eight-acre wildlife habitat and management area on dredge spoil at Nott Island in the lower Connecticut River (Corps of Engineers, 1977a). Another project designed to expand a salt marsh at Branford Harbor, Connecticut, met with considerable opposition from nearby residents and was abandoned.

In addition to the Corps programs, private corporations are becoming increasingly involved with the establishment of marshes on dredged materials as a means of habitat restoration and shore erosion abatement. One company, Environmental Concern, Inc., has successfully established several small marshes, primarily along the Chesapeake Bay (Environmental Concern, Inc., 1977). This company also undertakes routine testing and analyses of seed germination and plant growth in sediments contaminated with potentially hazardous materials such as oils, biocides, and heavy metals.

In Rhode Island, there has been little consideration of building salt marshes with channel or harbor dredgings. The only attempt at salt marsh development occurred in 1975, when it was proposed that a marsh be established in Watchemoket Cove, East Providence, from dredge spoil (394,000 yd^3) taken from the Port of Providence (Tippie, 1975). The proposal was dropped because the existing high wildlife values of the area would have been considerably altered by constructing a marsh and because of opposition from the city of East Providence.

In order for marsh development to be economically feasible, the disposal location must be within hydraulic pumping distance of the dredging area (one to three miles). Total costs must include those related to spoil containment and grass planting, both of which can be substantial, depending on the size of the project.

The successful establishment of salt or brackish marshes in Rhode Island depends on many factors, the most important of which includes sediment elevation relative to mean sea level, degree and type of containment, protection from erosion by tidal action and waves, salinity, and the amount of sunlight reaching the grasses. Recent research (much of it supported by the DMRP) has shown that the type of sediments used or the degree to which they are polluted is of minor importance in the success of a manmade salt marsh. Disposal sites should be located in small coves, embayments, or similar areas protected from high wave or tidal forces, since this reduces the need for artificial containment and reduces costs.

Hydraulic dredging and pumping to a marsh containment area should be undertaken during the winter or early spring months when adjacent recreational activities are less intense and when odor will be minimized. If possible, contaminated spoil should be covered with a layer of clean sediments. The spoils should be planted with marsh grasses immediately following disposal and dewatering of the sediments.

Marshes should not be built on existing recreational shellfish beds, on important fish breeding areas, or in other areas containing significant aquatic resources such as eelgrass beds. Obviously, marshes should not be constructed in areas which might interfere with navigation or which could reintroduce sediments into the newly dredged area.

The following are examples of areas that should be considered for marsh building because of their proximity to dredging locations, their apparent suitability in terms of engineering and construction requirements, and their potential for acceptance by state and local governments and nearby residents.

A. Watchemoket Cove, East Providence. Although earlier attempts at establishing a marsh were rejected, the proximity of this site to dredging areas and the background information already gathered for this site indicate that a salt marsh could be successfully established. A smaller-sized marsh than originally envisioned would probably receive a more positive response.

B. Rock Island, Warwick. Situated within hydraulic pumping distance from Pawtuxet Cove, the small artificially produced cove between Rock Island and the mainland south of a riprapped walkway would appear suitable for a six- to seven-acre marsh.

C. Greenwich Cove, East Greenwich/Warwick. Although this site is not immediately adjacent to a proposed dredging project, the extreme southern tip of this embayment provides well-protected shallow water away from high population densities. Since it is already affected and partially filled by a municipal dump. marsh grasses could probably be established easily and a minimum of containment would be necessary. Dredge spoils would probably have to be barged to the site.

D. Allen Harbor, North Kingstown. This harbor is near the former Quonset/Davisville CBC headquarters and served many functions, including anchorage, marina, dredge spoil disposal area, and recreational shellfishing area. The Navy also filled in a large section of the harbor as part of their dump on the western shore. Some patches of what was once a large salt marsh have survived. It would be possible to restore portions of this area by planting additional salt marsh; this would also improve the visual quality of the area. Another alternative would be to elevate the former spoil area just west of Calf Pasture Point with additional sediments. This area has not been maintained, and has poor drainage characteristics that could be corrected by additional material.

E. Point Judith Pond, Narragansett/South Kingstown. During previous dredging operations in the channels within the pond, considerable acreage of marsh and lowlands were filled. The frequent maintenance dredging required within this pond presents opportunities for the reestablishment of salt marsh within several small coves.

F. Coves in the Pawcatuck River, Westerly. Small fringe marshes in coves along the Pawcatuck River such as Foster, Potter, Colonel Willie, or Babcock Cove could be enlarged by small amounts of dredged materials from channel maintenance dredgings.

G. Spectacle Cove, Portsmouth. Sand and gravel mining has taken place in this cove for many years and has disturbed the existing marsh. Since this site is protected from high waves and currents, marsh reestablishment or expansion would appear feasible. The site may be within hydraulic pumping distance of Mount Hope Bay.

H. Drowne Cove, Barrington. Disposal of dredged material here in the past has left unsatisfactory conditions. Much of the spoil that was placed on the shore of the cove has since eroded into the channel and restricted tidal flow into and out of the cove. Spoil areas covered with Phragmites (reed) have now become mosquito-breeding areas. A picturesque and valuable salt marsh could be established in Drowne Cove by grading the existing dredged material and using additional materials taken from the Bullock's Point channel dredging maintenance project. Little, if any, structural containment or bulkheading would be needed. Also, a regularly flushed salt marsh in this area would lessen the present mosquito-breeding problem, since much of the standing water would be eliminated.

Island building. Although no attempt has been made in Rhode Island to create islands out of dredge materials, existing islands adjacent to dredging areas have been used as disposal sites. Cornelius Island (Wickford Harbor), Spar Island, and Common Fence Point (Mount Hope Bay) are examples. No provisions were made to provide spoil bulkheading or containment at these areas. As a result, sediments exposed to wave action have eroded. This is most evident at Spar Island.

Containment by earthen dikes, sheet piling, or rock enclosures is an expensive but effective technique for minimizing erosion. Cost estimates for a steel containment structure have been made for Spar Island by the Corps of Engineers and run between $12 and $15 million. This project would entail building a 100- to 200-acre island on the present Spar Island site, which would accept spoil from the Fall River/ Tiverton channels. However, these high costs put into question the feasibility of any island-building project. The CRMC has recently requested the Corps of Engineers to determine the cost feasibility of such a project using materials other than steel for containment.

There are a number of locations within Narragansett Bay and elsewhere where island expansion should be considered:

A. Dyer Island. This small shrub-covered island lies to the east of the former South Prudence subaqueous disposal site. The shoreline of this island is primarily cobble, and has a slowly eroding embankment along the upper border of the beach. A small salt marsh borders shallow waters on the island's south side which could be enlarged with dredged material. Containment would be necessary, since part of the potential disposal area lies in open water and is exposed to waves from the south. The island is low and has little significance at present for wildlife, although a colony of gulls reportedly nests on the uplands. The elevation of the entire island could be substantially increased with dredged materials. The island could be used in conjunction with commercial waterfront activities at nearby Melville or it might be managed as a wildlife habitat as part of the Bay Islands Park System.

B. Rose Island. A proposal has been made by the owners of Rose Island, which lies south of the Newport Bridge, to enlarge it from 14 to approximately 90 acres. This would be accomplished by bulkheading the island's north end to extend it as far as the Bridge, and then filling it with materials dredged from Newport Harbor and elsewhere (CMTS, 1975). While this proposal is ambitious in scope, the potential does exist to build up the island's north end substantially.

C. Common Fence Point. Although this area has already been used for dredge disposal, some portions can accommodate additional material. Proper placement of material, combined with a program to stabilize the sediments with beach grass or other vegetation, could provide additional protection to houses at the Point.

D. Point Judith Pond. Consideration should be given to building a new island out of sediments from Point Judith Pond channel maintenance projects. One possible location would be west of Great Island, in shallow areas between the east and west channels. Most of the existing islands in the pond are developed, and a small island preserved for nesting bird colonies would increase the natural values of the pond. Although a small spoil island in each of the coastal ponds might be desirable from the perspective of encouraging wildlife, one located in Point Judith Pond might be more feasible due to the altered and largely developed condition of this pond and its proximity to dredging projects.

Beach restoration. As shown in Table 1, clean sediments, particularly those from Point Judith Pond, have on several occasions been put on beaches. This makes good sense in light of the high quality of the sediments and the fact that most of the sediments dredged from channels came from the beaches in the first place. Some sediments from the 1977 dredging project in Point Judith Pond were trucked to East Beach, Charlestown, to give temporary storm protection to houses on the barrier beach. While it is expected that little long-range protection will be provided to the houses by the additional sand, it has improved the visual and buffering qualities of the beach at least temporarily and given added protection to the enclosed pond. Beach nourishment is a technique widely used along barrier beaches and islands in the southeastern United States. Most of Rhode Island's south shore beaches are in need of nourishment. Environmental problems associated with the activity have been shown to be minor.

Channel relocation. Sandy Point, a sand spit located within Little Narragansett Bay, was separated from Napatree Point by overwash during the 1938 hurricane. Since that time, Sandy Point Island has gradually moved to the north and west as winds and current worked on the sands. The western portion of the island now encroaches on the dredged channel along the Connecticut shore. This channel required spot dredging in 1977, and will undoubtedly be a major maintenance problem in the future as more sand from Sandy Point Island is transported into the channel.

To offset this problem and to facilitate access to the Bay from Block Island Sound, a new channel should be considered between Napatree Point and Sandy Point Island. This would shorten the distance between Long Island Sound and the Pawcatuck River considerably and would take advantage of the present patterns of tidal currents. The amounts of dredged material created by relocating the channel would not be large, since the channel would only be six feet deep. Relocating the channel closer to Napatree Point would facilitate the maintenance dredging/disposal of channel sediments. Sand which rounds Napatree Point and enters the channel could be easily pumped back onto the Napatree barrier beach, thus increasing the resistance of the beach to storms and enhancing the protection it affords to Little Narragansett Bay.

Since there are few pollutants in these sediments and small amounts of silt, and since the proposed transfer will be between similar physically controlled environments, the adverse impacts of channel relocation will be minimal.

Potential Large-Scale Solutions

Spoil Island in Mount Hope Bay. The idea of enlarging Spar Island in Mount Hope Bay with dredged materials has recently attracted considerable attention. This is because the easternmost of two islands at this location already consists of unconfined dredge spoils and the large volumes of organic sediment in the Bay channels would otherwise have to be transported to a large dump site offshore. The state of Massachusetts has seriously questioned the desirability of carrying the dredge material offshore.

The positive aspects of an island in Mount Hope Bay include:

1. location of the site near the state line, where both states would share the benefits as well as the impacts;

2. location away from habitations where odor and safety might be problems;

3. minimum effect on shellfishing, since this activity is presently prohibited within Mount Hope Bay; and

4. the observed stability of the present spoil island and its use by area residents for recreation.

One of the negative aspects of this proposal is the necessity of using hydraulic dredging, which produces a slurry difficult to contain and slow to solidify and which produces turbid effluent. Turbidity can be reduced by allowing adequate settling time and by good weir construction, however. Island building for habitat development need not be carried out in a single project, and could partially solve the need for a long-term regional disposal site.

Research has been carried out by the Corps of Engineers Dredged Material Research Program on the techniques and costs of island habitat development. The Coastal Resources Management Council has requested that the DMRP and the New England Division of the Corps at Waltham, Massachusetts, provide information that would determine the cost and engineering feasibility of island construction in Mount Hope Bay. Information on the following subjects will be needed if the Spar Island proposal is to be pursued:

A. Minimum protection. It is desirable to minimize the size and expense of retaining structures. Examination of the present shoreline and wind speed records permits some projections to be made on the stability of the spoils. Climatological data show the predominant wind direction to be southwest in the summer, with speeds commonly between 8 and 16 mph and from the north or northwest in the winter. The northwest-southeast orientation of Spar Island is apparently in equilibrium with summer winds. The present deposits of gravel and small boulders in the intertidal area are sufficient to protect the island from erosion. The wave energy is too great for salt marsh establishment, however, as only a small patch is found on the present island. A configuration which might be examined for an enlarged island would include shoreline protection on the north and south sides with a channel leading to beach or marsh areas between.

B. Shellfish resources. The Bay was closed to shellfisheries in 1940 because of sewage contamination, and little information exists on the present quahog population in Mount Hope Bay. This information is needed, however, since it can be expected that the water quality classification of the Bay will improve when modifications are made to the Fall River treatment plant. With improvement in water quality, several hundred acres could become available for shellfishing.

Examination of recent data provided by consultants for the Brayton Point power plant indicate that although fecal bacteria are high and variable due to sewage, the benthic and planktonic populations of the Bay are productive and typical of estuaries in this region. The relatively hardy quahog would be expected to do well here. The Rhode Island Department of Health, Food Product Safety Division, samples quahogs at three stations in Mount Hope Bay and has found recruitment of small quahogs as well as unharvested older individuals. Quahogs prefer shelly and sandy mud over pure mud and are likely to be abundant in shallow areas (6-15 feet deep) around Spar Island. A benefit of island building would be the creation of intertidal areas which would support populations of soft-shell clams.

C. Pollutant release. The sediments found in the Taunton River north of the Braga Bridge are high in organic matter and mercury content, which could possibly make them unsuitable for island development. It should be kept in mind, however, that since the proposed project is for improvement dredging (deepening the existing channel), a high percentage of the materials removed would be uncontaminated and would therefore present few problems.

The possibility of pollutant release from hydraulic dredging effluents and from marshes on a spoil island was discussed in the Environmental Impact Statement for Fall River. Since that document was prepared, more test results on the effects of dredging and disposal on water quality have become available from the Corps of Engineers Dredged Materials Research Program (Corps of Engineers, 1977a). In general, these indicate that during open water disposal only ammonium is likely to reach toxic levels, and then only in areas of poor mixing. There is a strong tendency for metals in settled sediments to remain in association with particulate matter; translocation of heavy metals from dredged material into the leaves and stems of marsh plants seldom occurs in significant amounts (Corps of Engineers, 1977b).

D. Attitude of nearby residents. The proposed island would be very visible and would infringe on waters of two states and seven towns. Major dredging studies and dredging projects have been rejected in New England because of public sensitivity to the possible loss of property values, amenities, and natural resources. However, a well-designed island might enhance the existing natural values. In any event, consideration of island building in Mount Hope Bay should be preceded by a full evaluation of the public's sentiments.

Continued use of the Brenton Reef site. Continued use of this site should be seriously considered because of its closeness to Narragansett Bay, the detailed background studies which have been carried out there, its location shoreward of the most valuable fishing areas, and its history as a disposal site, which has already changed the fisheries and biological communities present at the site. Continued use of Brenton Reef should also be considered because studies have shown that no gross changes in pollutant levels or benthic composition have been found in areas directly adjacent to the spoil pile.

The relatively deep area (110 feet) southwest of the present spoil mound would probably be the best location for additional disposal. A tongue of natural silty sand extends into this area from the west and patches of spoil are already present as a result of its use as a temporary dump site in 1967 (Figure 4). While erosion has been observed on the shallowest portion of the present spoil mound, soft sediments appear to be stable most of the time at depths over 100 feet. Erosion and transport at the site is presently being studied by the Naval Underwater Systems Center (NUSC). Wave effects are being modeled by the University of Rhode Island, Department of Ocean Engineering, for EPA (Narragansett). If it is determined that little or no erosion can be expected, a one-quarter-square-mile area southwest of the present mound could contain three million cubic yards of spoil. Electronic navigation devices on spoil barges as well as marker buoys could be used to place spoil accurately. Bathymetric mapping, which is presently being carried out by NUSC, could be used to direct placement and avoid constructing a high pile extending into depths where erosion would be more likely.

A problem with the renewed use of this site is the presence of lobster, trawl, gill net, and fish trap fisheries nearby. Because of these fisheries, the site would not be suitable for fine-grained incohesive sediments that have a high potential for spreading or for sediments containing high levels of potentially toxic or tainting substances. It would be necessary to determine the location and density of lobster pots at the site, the tow paths of trawlers, and the areas used by the gill net fishery to assess the potential for disruption. Recent interviews with lobstermen indicate that pots are concentrated at the site from May to August and relatively small numbers are present until late fall. The concentration of pots is less than it is to the west on a ground known as "along the buoys" or further offshore. Lobster potting could probably continue within a half mile of the site while the dredged materials were being dumped.

The second most directly affected fishery would probably be the gill net fishery. Gill nets were first used in this area in 1978, and the number of fishermen and their fishing patterns is not well established. Close coordination with fishermen would be needed to minimize conflicts.

Brown's Ledge and other new sites in Rhode Island. When use of the Brenton Reef dump site ended, a new area was chosen for study as a regional dump site for Rhode Island and Massachusetts. An area southeast of Brown's Ledge was chosen, in part because of its location between areas fished by Rhode Island and Massachusetts fishermen.

A number of studies of the area were carried out in 1975-77 (URI, 1977). Bottom grabs, TV scans, side scan sonar, and diver examination showed that sediments vary from rippled sand and gravel in the shallower northwest corner of the site to smooth silty fine sand in the southeast corner. Shallow subbottom profiles made by the United States Geological Survey (USGS) showed marine sediments overlying glacial sediments. Unfortunately, these profiles could not be used to establish the present erosional-depositional status of the site.

Grab samples were taken to describe quantitatively the bottom fauna. The benthic populations vary with sediment type. Amphipods and other crustaceans are abundant in the shallower sandy areas, while polychaete worms and small bivalves dominate the silty area. Crabs and adult ocean quahogs are most abundant on sand. Fish caught near the study site were feeding heavily on crustaceans, as determined by gut analysis. Analysis of metals in the sediment and pollution-indicating bacteria in ocean quahogs by the FDA showed the expected low baseline levels.

Optical measurement of water turbidity showed that under natural conditions storm waves cause high near-bottom turbidity. In calm weather, bottom water is more or less turbid depending on whether it is flowing from a muddy or sandy area. Currents were measured with an instrument capable of recording high-frequency wave-induced currents. Most of the time, tidal currents at the site center were too slow to erode sediments; however, wave-induced currents during severe storms reached levels which would erode most sediments.

Bottom drifters released at the site indicated a non-tidal drift north-northeast during the winter and east during the spring. A computer model of suspended sediment dispersion from the study site suggested that a spoil-derived plume would be detectable from background suspended matter levels two or three miles in the northeast direction. Observations of buoys indicated that lobster fishing is carried out north and west of the site. Interviews with fishermen established that occasional tows for finfish were made near the southeast corner of the site.

The most serious scientific problem with the Brown's Ledge site is the difficulty of predicting to what degree the storm-induced currents will erode spoil. Rippled sediments and high current velocities during storms both suggest the possibility of erosion. It was suggested in the Fall River DEIS that moving the site somewhat into deeper water would reduce the possibility of erosion, but that this could lead to conflicts with the trawl fishery.

In response to the concerns of sport and commercial fishing interests throughout the region, the Commonwealth of Massachusetts has opposed using Brown's Ledge for any Massachusetts projects. If the concept of a bistate project is abandoned and Brown's Ledge is determined as unfeasible, areas close to Narragansett Bay should be examined as alternatives. There has been no systematic effort to search for a new area for Rhode Island use; all studies have been focused on Brown's Ledge.

In 1976, the New England Division of the Corps of Engineers, in cooperation with the National Oceanic and Atmospheric Administration (NOAA), conducted a submersible survey of potential disposal sites in Rhode Island Sound (Chase, 1977). The areas examined were in similar locations topographically to the Brown's Ledge site in that they are on deep bottom between two rocky glacial moraines, the first of which crosses Rhode Island Sound from Point Judith to Brown's Ledge and Cuttyhunk, and the second of which extends from Block Island to Cox Ledge and Martha's Vineyard (Figure 4).

Chase found that the middle of the shallow valley between the moraines (C-20) and "Deep Hole" (C-7) adjacent to Cox Ledge had the finest sediments and appeared well suited as potential disposal sites. These areas have since been determined to be primary trawling grounds for commercial fishermen and thus should not be further considered.

Several other potential sites were located in depressions between portions of the inner moraine. Chase's stations C-11 and C-12 are of some interest because they are relatively

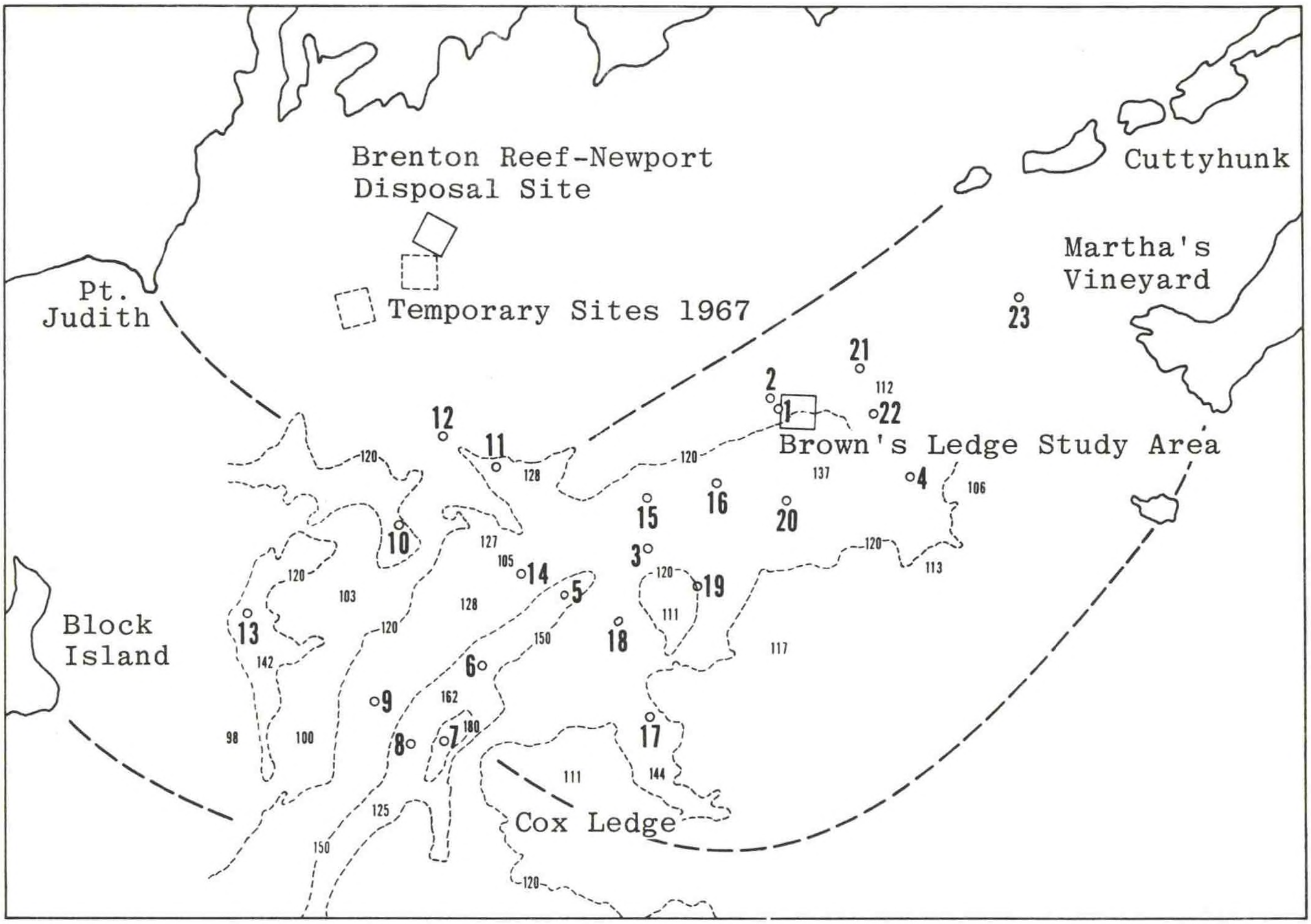


Figure 4. Location map of Rhode Island Sound. Elevated rocky glacial moraines are shown by heavy dashed lines; numbered circles indicate submersible dives (C stations) made by Chase (1977). Selected contours are given in feet.

close to Narragansett Bay, are on soft bottom, and are not used by trawlers. Recent interviews with lobster fishermen, however, have established that this "pear-shaped hole" area is an important ground in late summer and fall, when lobsters use it as a migration route.

If a new offshore site other than Brown's Ledge is chosen, concerns should focus on the fisheries in nearby areas and the physical stability of the bottom. Other concerns include wave-induced erosion, the direction of sediment dispersion, and the effects on the productivity of biological communities. Data on Brown's Ledge for contaminants, benthic communities, and turbidity can be used as baselines for adjacent areas. The presence of coarse rippled sand and smooth silty sand at similar depths (130 feet) in various parts of the area studied by Chase shows that bottom stability is a function of topography as well as depth. Furthermore, exposures of clay at shallow depths (60 feet) illustrate that some fine sediments represent older relict deposition patterns and are not indicative of present sediment or spoil movement conditions.

It is likely that the establishment of any new disposal site offshore will involve some restriction of or change to existing fisheries. From this perspective, lobster grounds should be chosen as primary target disposal site choices rather than trawling grounds. This is because lobster ground will recover quickly while trawling ground may be permanently lost if the deposited sediments are highly contaminated or if they contain large rocks and other solid debris. Some fisheries will be affected regardless of the exact offshore location, and we should be prepared to recognize that this is unavoidable. Providing that the total disposal area involved can be kept small enough, it may be in the state's best economic interest to balance the benefits the area presently gives to the fishing industry with those afforded all maritime industries by viable and competitive harbors and channels.

Recommended Demonstration Projects

The foregoing describes the many options available for the disposal and reuse of dredged materials from Rhode Island waters. Although some may be more practical than others from an economic or engineering standpoint, there are none that should be ruled out as potential options. The Dredged Materials Research Program of the Corps of Engineers makes a point of stressing that for any given dredging project there is no single disposal technique that must be considered the sole solution (Saucier, 1978). The DMRP has recommended many steps to ameliorate the environmental impacts associated with disposal activities and provides detailed accounts in various publications of the technologies available to achieve environmentally acceptable solutions for spoil disposal.

The use of dredged materials as a resource is a new concept in Rhode Island. It will undoubtedly be looked upon with varying degrees of skepticism. However, we must begin to broaden our efforts to solve our dredging and disposal problems. We therefore recommend that the state and, specifically, the Coastal Resources Management Council undertake the following two pilot projects, which are designed to: 1) determine the potential for various alternative dredged material disposal techniques in Rhode Island waters; 2) educate the public on the positive aspects of dredge/disposal technology; and 3) find at least a temporary solution to a selected dredging need.

<u>Creation of a salt marsh, Rock Island, Warwick</u>. Rock Island is a small bedrock outcrop island 50 yards from the shore and a half mile south of Pawtuxet Cove. It is vegetated by small shrubs and trees and contains some salt marsh. Large expanses of peat are present, indicating that salt marsh has grown here for a long time. The bedrock contains a variety of unusual fossils. As part of a 1966 Corps of Engineers improvement dredging project in Pawtuxet Cove, a stone seawall was constructed from the island's northern tip up to the Cove entrance. A similar stone walkway connects the island to the mainland, forming a small cove between the mainland and the island which has subsequently been partially filled by natural sedimentation.

It is proposed that a small salt marsh be constructed in this cove on dredged material pumped hydraulically from Pawtuxet Cove. Pawtuxet Cove sediments have been determined to be contaminated with heavy metals and organic chemicals (The Research Corporation of New England, 1978; Jungclans et al., 1977). The Corps of Engineers does not recommend offshore disposal of contaminated sediments, yet considers dredging needs in this area a high priority. Recent studies of the assimilation of sewage wastes by wetlands indicate that salt marshes (as well as other wetlands) play a significant role in providing free waste treatment of contaminated waters (Valiela et al., 1975). There is little reason to believe that a salt marsh established at Rock Island out of dredge spoils would not serve in a similar capacity.

Salt marsh development in this area would have several other advantages:

1. Pawtuxet Cove could be maintenance dredged within the time frame established by the Corps of Engineers (fiscal year 1979).

2. Polluted dredge spoil would be contained within the same general area, not transported elsewhere possibly to impact higher water quality areas.

3. Costs of barge transport would be eliminated. Overall costs of dredging and disposal should be relatively low.

4. The establishment of a salt marsh would help to offset past losses of this highly productive habitat in the upper Bay.

5. Creation of a marsh would increase the visual diversity and attractiveness of the state-owned picnic area on the western shore near the site.

6. Although some containment structure would probably be required on the cove's south side, the existing opening is narrow enough and wave energies low enough so that large structures would be unnecessary. If rock containment is determined to be desirable, at least some of this material could be provided from a pile of excess rock left over from the construction of the Pawtuxet Cove breakwater. It is felt, however, that sandbags would provide adequate containment for this project.

7. Since this marsh would be established within one of Rhode Island's most polluted marine areas and with contaminated materials, it would give valuable opportunities for a long-term evaluation of the containment of hydraulically dredged materials. Ongoing studies in this area have determined that the organic pollutants present are strongly associated with sediments, and there is good reason to believe that transfer into the water column will be minimal. Unique compounds in this sediment can be used as sensitive tracers of spoil movement for monitoring purposes.

The Coastal Resources Management Council has begun to investigate the feasibility of this project, and is undertaking experiments where salt marsh grasses are transplanted into containers filled with sediments from the area that would be dredged and then embedded into the proposed disposal area. Heavy metal uptake by the grasses will be analyzed. The Corps of Engineers is likewise investigating the possibility of building a marsh in this area (see Appendix B).

If this project is undertaken, it is especially important that a long-range monitoring program be carried out on the disposal site both before and after the disposal of dredged material.

Detailed information on water quality, the potential for sediment solidification, erosion by waves and tides, grass growth, odor, release of pollutants, changes to current patterns and benthic communities, and holding capacity should be gathered prior to construction. Following disposal, data should be obtained on the success of the growth of marsh grasses, the species and numbers of organisms which colonize the area, and the effects, if any, on biological communities immediately adjacent to the disposal area.

<u>Island construction, Point Judith Pond, Narragansett, South Kingstown</u>. Point Judith Pond has been dredged for navigation improvement and anchorage development on many occasions. Over the years the dredged material has been deposited in various places, including Brenton Reef, the Sand Hill Cove barrier beach, various lowlands and marshes on the pond's periphery, and, most recently, in a large parking lot adjacent to the fishing piers at Galilee. This latter site was temporary; the materials were subsequently hauled to other sites in the vicinity. Channels, especially in the lower reaches of the pond, tend to fill in rapidly, due primarily to sands that are carried into the pond through the breachway. Since this sediment is relatively clean, the most reasonable disposal technique would be to use as much of this material as possible for beach nourishment at Sand Hill Cove or at East Matunuck, its probable source.

Maintenance dredging of the upper reaches of the pond and improvement dredging of the yet-to-be-completed portions of the initial Corps project present a more complex problem. Unless the dredged material can be used for bulkheading or backfilling purposes, it must be transported out of the pond, resulting in a large increase in the total cost of the project. Recently announced plans of the New England Power Company to dredge 17,000 yd^3 of channel material from the upper pond in order to provide barge access to Route 1 would also add considerably to the total amounts of spoil from this pond. Considering these historical and proposed uses, a new disposal option may be needed.

We propose that a small island be constructed within Point Judith Pond. One potential site may be west of Great Island, directly adjacent to the existing channel on the western shoreline in existing shallows. Since many of the islands in the pond are heavily developed, the establishment of an island which would be kept as open space for wildlife habitat would increase the diversity and aesthetic values of the pond system. Other advantages include:

1. Cost of disposal would be considerably lower than transport offshore.

2. Badly needed habitat would be provided for colonially nesting waterbirds which are being forced from traditional nesting grounds on other islands and barrier beaches.

3. Since wave and tidal velocities in the pond are low, bulkheading might be minimal or even unnecessary.

4. Pollution problems would be low due to the high-quality sediments which predominate in the pond.

5. Shallows around the island could provide excellent habitat for soft-shelled clams.

The proposed island should be located in an area of natural sedimentation. If such a shallow area is chosen, existing current regimes would remain largely unaffected. The problems of odor will be minimized if dredging is undertaken during the fall or winter months.

APPENDIX A

The following tables present the results of sediment sample tests undertaken by the Corps of Engineers in 13 Rhode Island dredging project areas. The tables give levels of metals and other polluting substances found in each sample. Corps of Engineers files in Waltham, Massachusetts, contain data on more variables than are listed here. At the bottom of each table is the classification given to each sample assigned by the authors in a process modeled on the Connecticut classification scheme. The suggested permissible range limits for each potential pollutant in each class are listed at the right of the tables. The classification method differs slightly from Connecticut's in that their two-step process (classifying metals and non-metal contaminants separately) has been combined. Summary classification results for each area are presented in Table 5 in Section III of this report.

All sediment components labeled with an asterisk (*) are in excess of Class III guidelines. In such cases, the entire sample has been designated Class III, which in the Connecticut scheme is described as "potentially degrading" or "potentially hazardous." Sediment components identified with a question mark (?) fall within Class II guidelines. If one or more components are found to be Class II, the entire core sample is so classified. The effects of these sediments on biological systems are questionable and, depending on the disposal site selected and disposal method used, can be either non-degrading or potentially degrading. Since in many cases only one sediment component has been identified as being in Class II or Class III, it is possible that the toxic effects of such materials would be low if other core samples from the same general area are of better quality. Class I sediments are considered non-degrading and non-hazardous and would be appropriate for a variety of disposal options.

AREA LOCATION: Apponaug Cove

Sediment Core #	PE-1		PE-2		PE-3		GE-4		PE-5		GE-5		GE-6		Conn. Sediment Class levels		
Sample Depth (Ft.)	0-0.8		0-1.2		0-1.8		surface		0-.5		surface		surface		I	II (?)	III (*)
Sounding (Ft.)	7.9		9.6		9.2				7.9		7.9		10.2				
% Silt /Clay	29.8		48.3		100*		31.6				22		19.4		60	60-90	90
Sample Depth (Ft.)	0-.25	.6-.8	0-.25	1-1.2	0-.25	1-1.2	surf.		0-.25	.3-.5			surf.				
% Solids	25.7*	56.3?	36.8*	72.7	39.9*	50.9?	40.85?			65.8			64.7		60	60-40	40
% Volatile Solids	14.5*		10.03*		6.22?		7.2?		.98		No Su	Data pplied	1.66		5	5-10	10
Hexane Soluble Fraction (ppt.)	7.5?		3.7		2.25		3.26		.33				1.04		5	5-10	10
Metals (ppm)																	
Mercury (Hg)	2.5*	.45	2.3*	.057	1.1?	.065	1.4?		.032	.061			.42		.5	.5-1.5	1.5
Lead (Pb)	777*	43	272*	83	160?	39	230*		33	21			56		100	100-200	200
Zinc (Zn)	855*	156	543*	44	265?	79	236?		38	27			62		200	200-400	400
Cadmium (Cd)	6.2?	1.4	6.5?	2.7	5.0?	3.1	5.9?		2.2	1.2			2.5		5	5-10	10
Chromium (Cr)	1127*	18	730*	41	370*	43	350*		33	15			46		100	100-300	300
Copper (Cu)	428*	85	217?	66	140	39	230?		27	15			43		200	200-400	400
Nickel (Ni)	78?	36	33	17	30	24	29		16	9.1			19		50	50-100	100
Vanadium (V)	94?	57	87?	44	115?	63	98?		43	49			71		75	75-125	125
Arsenic (As)	9.9	2.6	2.0	3.2	4.2	6.0	4.4		1.8	2.8			2.1		10	10-20	20
Suggested Classification	III	II	III	II	III	III	III		I	I			I				

AREA LOCATION: Block Island-Harbor of Refuge

Sediment Core #	GE-1-75	GE-2-75	GE-3-75	GE-4-75	Conn. Sediment Class levels I	II (?)	III (*)
Sample Depth (Ft.)	surface	surface	surface	surface			
Sounding (Ft.)	0	12.5	13.5	14.3			
% Silt /Clay	3.0	5.3	15.8	1.6	60	60-90	90
Sample Depth (Ft.)	surf.	surf.	surf.	surf.			
% Solids	76.3	71.08	73.9	78.2	60	60-40	40
% Volatile Solids	.42	.64	.73	.36	5	5-10	10
Hexane Soluble Fraction (ppt.)	.21	.11	.16	0	5	5-10	10
Metals (ppm)							
Mercury (Hg)	.072	0	0	0	.5	.5-1.5	1.5
Lead (Pb)	26	34	35	10	100	100-200	200
Zinc (Zn)	18	24	24	15	200	200-400	400
Cadmium (Cd)	.5	.5	1.1	1.1	5	5-10	10
Chromium (Cr)	7.9	7.9	14	7.7	100	100-300	300
Copper (Cu)	16	16	16	10	200	200-400	400
Nickel (Ni)	26	13	14	13	50	50-100	100
Vanadium (V)	18	18	35	18	75	75-125	125
Arsenic (As)	.5	1.0	1.4	1.5	10	10-20	20
Suggested Classification	I	I	I	I			

AREA LOCATION: Block Island-New Harbor

Sediment Core #	GE-1	GE-2	GE-3	GE-4	PE-1					Conn. Sediment Class levels I	II (?)	III (*)
Sample Depth (Ft.)	surface	surface	surface	surface	0-0.3							
Sounding (Ft.)	19.4	4.0	19.0	19.5	19.4							
% Silt /Clay	15.6	3.1	9.4	0	11.4					60	60-90	90
Sample Depth (Ft.)	surf.	surf.	surf.	surf.								
% Solids	68.7	75.9	71.3	77.8	66.3					60	60-40	40
% Volatile Solids	1.94	.64	1.34	.17	1.67					5	5-10	10
Hexane Soluble Fraction (ppt.)	.64	.007	.26	ND	.51					5	5-10	10
Metals (ppm)												
Mercury (Hg)	.26	3.8*	.21	.2	.5					.5	.5-1.5	1.5
Lead (Pb)	34	19	15	18	118?					100	100-200	200
Zinc (Zn)	58	40	29	17	57					200	200-400	400
Cadmium (Cd)	1.3	.79	.84	.77	.72					5	5-10	10
Chromium (Cr)	7.6	4.7	5	4.6	10					100	100-300	300
Copper (Cu)	22	18	16	11	13					200	200-400	400
Nickel (Ni)	22	13	21	13	27					50	50-100	100
Vanadium (V)	23	26	28	21	36					75	75-125	125
Arsenic (As)	1.0	.11	.84	.31	2.4					10	10-20	20
Suggested Classification	I	III	I	I	I							

AREA LOCATION: Brushneck Cove

Sediment Core #	PE-1		PE-2		PE-3		PE-4		PE-5		PE-6		PE-7		PE-8		PE-9		Conn. Sediment Class levels		
Sample Depth (Ft.)	0-1.65		0-1.45		0-1.5		0-1.45		0-1.4		0-1.3		0-1.25		0-1.4		0-1.4		I	II (?)	III (*)
Sounding (Ft.)	5.0		6.9		5.7		5.1		6.1		4.9		4.5		4.5		3.0				
% Silt /Clay	56.5		81.5?		61.0?		63.6?		70.2?		58.5		57.5		70.9?		67.6?		60	60-90	90
Sample Depth (Ft.)	0-.25	1-1.2	0-.17	1-1.2	0-.17	1-1.2	0-.17	1-1.2	0-.17	1-1.2	0-.17	1-1.2	0-.17	1-1.2	0-.17	1-1.2	0-.17	1-1.2			
% Solids	57.1?	52.1?	42.2?	52.1?	73.3	53.7?	40.1?	57.7?	35.8*	40.2?	38.5*	50.1?	19.6*	55.8?	29*	62.2	45.9?	43.7?	60	60-40	40
% Volatile Solids	3.14		4.77		1.22		6.73?		8.9?		6.59?		14.1*		9.5?		5.3?		5	5-10	10
Hexane Soluble Fraction (ppt.)	0.86		1.04		0.42		1.22		4.7		1.84		5.9?		3.0		1.81		5	5-10	10
Metals (ppm)																					
Mercury (Hg)	0.53?	0.11	0.64?	0.16	0.14	0.15	0.13	.035	.12	.093	.1	.08	.83?	.076	.69?	.06	.39	0	.5	.5-1.5	1.5
Lead (Pb)	53	19	57	12	33	19	100	17	168?	99	130?	20	204*	11	207*	16	100?	14	100	100-200	200
Zinc (Zn)	119	54	152	61	52	48	215?	31	357?	55	239?	58	408*	40	379?	45	174	87	200	200-400	400
Cadmium (Cd)	2.5	2.7	4.7	3.8	1.4	1.9	3.5	2.4	5.6?	5.0?	5.2?	2.0	10*	2.5	6.9?	2.3	4.9	2.3	5	5-10	10
Chromium (Cr)	60	35	81	35	19	34	145?	32	168?	45	119?	28	143?	22	110?	29	74	32	100	100-300	300
Copper (Cu)	74	35	85	46	46	11	85	14	190	99	130	36	204?	14	152	97	74	41	200	200-400	400
Nickel (Ni)	21	23	28	12	8.2	22	30	35	50?	15	42	24	82?	11	41	9.7	26	27	50	50-100	100
Vanadium (V)	35	38	24	38	27	37	50	35	56	50	52	40	102?	37	69	32	44	46	75	75-125	125
Arsenic (As)																			10	10-20	20
Suggested Classification	II	II	II	II	I	II	II	II	III	II	III	II	III	II	III	I	II	II			

AREA LOCATION: Bullock's Cove

Sediment Core #	PE-1		PE-2		PE-3		GE-1		GE-2		GE-3		Conn. Sediment Class levels		
Sample Depth (Ft.)													I	II (?)	III (*)
Sounding (Ft.)															
	N. Anchorage		N. Anchorage		S. Anchorage		Entrance		App. Channel		App. Channel				
% Silt /Clay													60	60-90	90
Sample Depth (Ft.)	0-.1	1-1.1	0-.1	1-1.1	0-.1	1-1.1	0-.1		0-.1		0-.1				
% Solids													60	60-40	40
% Volatile Solids	2.5	--	11.7*	--	10.7*	--	0.9		0.4		2.2		5	5-10	10
Hexane Soluble Fraction (ppt.)	1.6	--	4.1	--	11.7*	--	0.5		0.4		1.6		5	5-10	10
Metals (ppm)															
Mercury (Hg)	1.6*	0.6?	0.82?	1.23?	1.21?	2.01*	0.17		0.14		0.39		.5	.5-1.5	1.5
Lead (Pb)	56	163?	87	259*	273*	222*	21		12		44		100	100-200	200
Zinc (Zn)	107	28	156	421*	528*	350?	54		31		123		200	200-400	400
Cadmium (Cd)													5	5-10	10
Chromium (Cr)													100	100-300	300
Copper (Cu)	129	295?	315?	712*	956*	746*	62		36		173		200	200-400	400
Nickel (Ni)													50	50-100	100
Vanadium (V)													75	75-125	125
Arsenic (As)													10	10-20	20
Suggested Classification	III	II	III	III	III	III	I		I		I				

AREA LOCATION: Greenwich Cove

Sediment Core #	PE-1		PE-2		Conn. Sediment Class levels I	II (?)	III (*)
Sample Depth (Ft.)	0-1.8		0-1.25				
Sounding (Ft.)	15.8		14.6				
% Silt /Clay	80?		78.2?		60	60-90	90
Sample Depth (Ft.)	0-.25	1-1.2	0-.25	1-1.2			
% Solids	39.2*	48.4?	33.0*	41.8?	60	60-40	40
% Volatile Solids	14*		8.44?		5	5-10	10
Hexane Soluble Fraction (ppt.)	5.1?		6.88?		5	5-10	10
Metals (ppm)							
Mercury (Hg)	1.6?	1.1?	2.0*	0.15	.5	.5-1.5	1.5
Lead (Pb)	143?	90	170?	64	100	100-200	200
Zinc (Zn)	510*	90	352?	100	200	200-400	400
Cadmium (Cd)	4.1	2.5	3.6	3.2	5	5-10	10
Chromium (Cr)	230?	41	212?	60	100	100-300	300
Copper (Cu)	184	58	194	48	200	200-400	400
Nickel (Ni)	31	21	31	24	50	50-100	100
Vanadium (V)	82?	66	164*	64	75	75-125	125
Arsenic (As)					10	10-20	20
Suggested Classification	III	II	III	II			

AREA LOCATION: Little Narragansett Bay

Sediment Core #	GE-1		GE-2		PE-3		PE-4		GE-5		PE-6		PE-7		Conn. Sediment Class levels I	II (?)	III (*)
Sample Depth (Ft.)	surface		surface		0-1.5		0-1.2		surface		0-1.65		0-1.5				
Sounding (Ft.)	1.2		9.9		9.3		9.7		9.0		5.0		11.5				
% Silt /Clay	0.2		6.8		78.8?		21.4		5.3		1.9		89.7?		60	60-90	90
Sample Depth (Ft.)	surf.		surf.		0-.25	1-1.2	0-.17	1-1.2	surf.		0-.17	1-1.2	0-.17	1-1.2			
% Solids	91.6		76.9		29.0*	57.5?	70.2	79.2	80.7		78.4	83.0	34.2*	42.6?	60	60-40	40
% Volatile Solids	.13		.55		10.3*		1.47		.58		.42		8.43?		5	5-10	10
Hexane Soluble Fraction (ppt.)	0		.51		3.5		.48		.16		.17		2.49		5	5-10	10
Metals (ppm)																	
Mercury (Hg)	.033		0		.59?	.17	.08	0	0		0	.04	.83?	.51?	.5	.5-1.5	1.5
Lead (Pb)	6.5		7.8		69	35	20	7.6	17		18	17	76	61	100	100-200	200
Zinc (Zn)	8.7		26		151	77	28	20	13		10	7.2	158	108	200	200-400	400
Cadmium (Cd)	.9		1.0		4.8	1.4	1.1	1.0	.5		.5	1.0	.4	1.9	5	5-10	10
Chromium (Cr)	5.7		11		78	40	17	8.6	6.4		6.6	6.3	87	135?	100	100-300	300
Copper (Cu)	11		26		138	94	25	30	6.4		5.1	4.8	140	38	200	200-400	400
Nickel (Ni)	5		8.8		38	17	9.7	8.6	8.4		8.7	5.0	29	33	50	50-100	100
Vanadium (V)	13		16		5	22	17	15	5.0		15	29	70	56	75	75-125	125
Arsenic (As)															10	10-20	20
Suggested Classification	I		I		III	II	I	I	I		I	I	III	II			

AREA LOCATION: Newport Harbor

Sediment Core #	PE-4		GE-5		GE-6		Conn. Sediment Class levels I	II (?)	III (*)
Sample Depth (Ft.)	0-0.7		surface		surface				
Sounding (Ft.)	24.2		25.0		19.6				
% Silt /Clay	74.4?		27.4		27.0		60	60-90	90
Sample Depth (Ft.)	0-0.2	0.5-.7	surf.		surf.				
% Solids	42.8?		68.7		47.0?		60	60-40	40
% Volatile Solids	5.5?		1.97		4.68		5	5-10	10
Hexane Soluble Fraction (ppt.)	4.58		0.57		2.47		5	5-10	10
Metals (ppm)									
Mercury (Hg)	1.2?	.33	.47		.28		.5	.5-1.5	1.5
Lead (Pb)	200*	38	87		110?		100	100-200	200
Zinc (Zn)	410*	55	93		190		200	200-400	400
Cadmium (Cd)	0.1	0.1	0.1		.13		5	5-10	10
Chromium (Cr)	65	34	41		68		100	100-300	300
Copper (Cu)	150	16	38		110		200	200-400	400
Nickel (Ni)	56	34	32		60		50	50-100	100
Vanadium (V)	37	41	15		68		75	75-125	125
Arsenic (As)	4.2	0.2	1.2		.9		10	10-20	20
Suggested Classification	III	I	I		II				

AREA LOCATION: Pawtuxet Cove

Sediment Core #	PE-1		PE-2		GE-5		PE-3		PE-4		Conn. Sediment Class levels I	II (?)	III (*)
Sample Depth (Ft.)	0-2.0		0-1.75		Surface		0-1.85		0-1.7				
Sounding (Ft.)	6.6		6.7		6.7		7.7		7.7				
	Mid-cove		South Cove		South Cove		Entrance Channel		Entrance Channel				
% Silt /Clay	98*	21	23		2.6		33.1	74.7?	19.1		60	60-90	90
Sample Depth (Ft.)	0-.25	1-1.2	0-.17	1-1.2	Surf.		0-.17	1-1.2	0.17	1-1.2			
% Solids	24.8*	54.4?	43?	72	85		52?	65	74	71	60	60-40	40
% Volatile Solids	17.6*	3.9	4.3	2.1	1.7		7.6?	3.2	1.3	2.3	5	5-10	10
Hexane Soluble Fraction (ppt.)	2.4		1.63		.71		7.09?		.1		5	5-10	10
Metals (ppm)													
Mercury (Hg)	2.51*	1.13?	.26	--	0		.98?	.14	.62?	.13	.5	.5-1.5	1.5
Lead (Pb)	565*	114?	82	25	54		195?	55	41	25	100	100-200	200
Zinc (Zn)	1250*	331?	192	39	85		459*	59	57	96	200	200-400	400
Cadmium (Cd)	5.6?	1.8	0.9	0.6	0.7		2.7	0.9	0.5	0.9	5	5-10	10
Chromium (Cr)	565*	166?	69	11	49		191?	40	22	17	100	100-300	300
Copper (Cu)	1211*	294?	151	22	78		363?	74	62	51	200	200-400	400
Nickel (Ni)	178*	44	46	28	16		65?	31	27	20	50	50-100	100
Vanadium (V)	194*	55	37	22	35		57	46	22	42	75	75-125	125
Arsenic (As)	13?	2.4	3.9	1.8	0.7		3.6	5.2	1.2	1.7	10	10-20	20
Suggested Classification	III	II	II	I	I		III	II	II	I			

AREA LOCATION: Pt. Judith Harbor

Sediment Core #	GE-8	GE-9	GE-10	GE-11						Conn. Sediment Class levels I	II (?)	III (*)
Sample Depth (Ft.)	surface	surface	surface	surface								
Sounding (Ft.)												
% Silt /Clay										60	60-90	90
Sample Depth (Ft.)												
% Solids										60	60-40	40
% Volatile Solids	.41	.63	.18	.6						5	5-10	10
Hexane Soluble Fraction (ppt.)	.09	.1	.08	.23						5	5-10	10
Metals (ppm)												
Mercury (Hg)	.42	.32	.24	.31						.5	.5-1.5	1.5
Lead (Pb)	15	20	21	14						100	100-200	200
Zinc (Zn)	28	18	27	30						200	200-400	400
Cadmium (Cd)	2.4	8.5?	1.8	4.1						5	5-10	10
Chromium (Cr)	4.8	4.7	4.6	6.9						100	100-300	300
Copper (Cu)	19	23	13	17						200	200-400	400
Nickel (Ni)	16	21	19	12						50	50-100	100
Vanadium (V)	27	18	18	31						75	75-125	125
Arsenic (As)	.85	1.4	.66	1.9						10	10-20	20
Suggested Classification	I	II	I	I								

AREA LOCATION: Providence River

Sediment Core #	PE-1		PE-2		GE-3		PE-4		PE-5		PE-6		GE-7		PE-8		PE-9		Conn. Sediment Class levels		
																			I	II (?)	III (*)
Sample Depth (Ft.)	0-2.1		0-1.6		surface		0-2.1		0-1.6		0-1.0		surface		0-1.3		0-1.8				
Sounding (Ft.)	37.7		38.7		39.5		41.2		39.2		39.2		41.6		43.5		43.5				
	Fields Pt.		Fields Pt.		Fields Pt.		Pomham Rock		Near Conimicut P.		Near Conimicut Pt.		Near Conimicut P.		Near Conimicut Pt.		Near Conimicut Pt				
% Silt /Clay	80?		84?		55		97*		67.5?		21		21		49		35		60	60-90	90
Sample Depth (Ft.)	0-.25	1-1.2	0-.17	1-1.2	surf.		0-.17	1-1.2	0-.17	1-1.2	0-.17	1-1.2	surf.		0-.17	1-1.2	0-.25	1-1.2			
% Solids	23.9*		22.4*		44?		35*		53?		70		78		53?		29*		60	60-40	40
% Volatile Solids	16.3*		16.5*		7.9?		8.2?		4.0		1.3		1.5		3.5		2.5		5	5-10	10
Hexane Soluble Fraction (ppt.)	2.73	--	5.97?		1.01		9.61?		2.11		.63		.88		.92		.35		5	5-10	10
Metals (ppm)																					
Mercury (Hg)	1.82*	0.53?	1.57*	0.6?	0.97?		0.62?	0.38	0.29	0.42	.06	.03	.09		.44	.29	.09	.03	.5	.5-1.5	1.5
Lead (Pb)	836*	258*	632*	171?	237*		173?	131?	62	90	17	12	21		48	108?	16	14	100	100-200	200
Zinc (Zn)	1379*	442*	1174*	376?	551*		341?	--	122	178	41	33	42		98	171	44	39	200	200-400	400
Cadmium (Cd)	12.5*	5.9?	10.8*	4.8	7.6?		2.6	--	1.6	1.8	1.1	1.0	1.0		1.5	2.5	2.2	1.1	5	5-10	10
Chromium (Cr)	460*	133?	379*	116?	237?		175?	--	62	108?	11	7	13		41	87	16	14	100	100-300	300
Copper (Cu)	1358*	514*	1140*	429*	695*		437*	--	130	91	42	29	34		109	109	38	39	200	200-400	400
Nickel (Ni)	199*	41	144*	38	57?		22	--	39	18	8	10	8		19	25	16	5	50	50-100	100
Vanadium (V)	105?	22	90?	22	38		52	--	31	72	17	15	16		15	37	22	11	75	75-125	125
Arsenic (As)	64*	14?	42*	15?	24*		19?	--	6.2	14.3?	1.3	0.3	6.8		9.5	9.5	2.8	3.5	10	10-20	20
Suggested Classification	III	III	III	III	III		III	III	II	II	I	I	I		II	II	III	III			

AREA LOCATION: Warwick Cove

Sediment Core #	PE-1		PE-2		PE-3		GE-4		GE-5		PE-6		PE-7		PE-8		PE-9		Conn. Sediment Class levels		
Sample Depth (Ft.)	0-1.7		0-1.55		0-0.9		surface		surface		0-1.1		0-1.95		0-1.8		0-.8		I	II (?)	III (*)
Sounding (Ft.)	11.5		10.6		9.6		7.2		9.1		8.7		6.6		8.0		6.6				
% Silt /Clay	77.1?		27.2		61.9?		9.4		6.3		77.2?		73.7?		70.3?		52.2		60	60-90	90
Sample Depth (Ft.)	0-.25	1-1.2	0-.25	1-1.2	0-.25	.7-.9	surf		surf		0-.25	.9-1.1	0-.25	1-1.2	0-.25	1-1.2	0-.25	.6-.8			
% Solids	47.2?	55.4?	56.5?	56.0?	39.4*	55.9?	75.2		74.8		46.7?	72.6	41.8?	46.9?	33.9*	63.7	33.9*	65.8	60	60-40	40
% Volatile Solids	5.6?	4.0	2.7	2.87	7.36?	3.8	1.0		1.3		6.03?	1.06	7.2?	5.9?	8.3?	3.7	9.57?	3.0	5	5-10	10
Hexane Soluble Fraction (ppt.)	3.35	--	2.25	--	3.3	--	.69		.70		3.55	--	4.6	--	2.98	--	4.06	--	5	5-10	10
Metals (ppm)																					
Mercury (Hg)	.51?	0	.34	.18	.98?	.13	.12		.13		.8?	.008	.99?	.46	1.0?	0	1.6*	0.2	.5	.5-1.5	1.5
Lead (Pb)	115	36	57	36	127?	43	29		16		81	28	110?	43	159?	22	147?	37	100	100-200	200
Zinc (Zn)	424*	51	85	86	229?	79	43		43		227?	61	263?	115	230?	57	342?	77	200	200-400	400
Cadmium (Cd)	4.2	3.6	1.4	1.4	2.0	2.9	1.1		0.5		1.6	1.1	2.9	2.7	2.4	1.3	4.7	1.8	5	5-10	10
Chromium (Cr)	64	18	28	29	76	29	8		13		64	83	72	43	59	25	88	15	100	100-300	300
Copper (Cu)	127	29	57	43	112	36	32		21		120	28	153	60	142	25	165	37	200	200-400	400
Nickel (Ni)	34	18	18	21	31	18	33		13		34	14	24	21	21	19	47	18	50	50-100	100
Vanadium (V)	34	29	57	57	81?	43	32		32		34	42	77?	68	47	50	94?	37	75	75-125	125
Arsenic (As)																			10	10-20	20
Suggested Classification	III	II	II	II	III	II	I		I		II	II	II	II	III	II	III	I			

AREA LOCATION: Wickford Cove

Sediment Core #	PE-1		PE-2		PE-3		PE-4		PE-5		PE-6		GE-7			Conn. Sediment Class levels		
Sample Depth (Ft.)	0-1.4		0-1.25		0-1.9		0-1.9		0-1.2		0-1.55		surface			I	II (?)	III (*)
Sounding (Ft.)	8.0		6.6		7.7		8.8		6.8		7.9		12.3					
% Silt /Clay	66.5?		87.4?	66.6?	98.3*		88.1?		90*		71.3*		7.6			60	60-90	90
Sample Depth (Ft.)	0-.25	1-1.2	0-.25	1-1.2	0-.25	1-1.2	0-.25	1-1.2	0-.25	1-1.2	0-.25	1-1.2	surf					
% Solids	33.2*	50.5?	35.2*	50.6?	37.3*	43.8?	51.6?	46.7?	32.6*	56.7*	45.1?	52.2?	75.8			60	60-40	40
% Volatile Solids	8.54?		8.71?		6.82?		5.09	6.1?	9.16?	4.26	6.62?	4.47	1.5			5	5-10	10
Hexane Soluble Fraction (ppt.)	2.22		3.49		2.14		1.63		2.91		1.77		.22			5	5-10	10
Metals (ppm)																		
Mercury (Hg)	4.4*	0.57?	3.2*	1.4?	2.7*	3.4*	1.4?	0.18	0.64?	0.2	0.81?	0	0			.5	.5-1.5	1.5
Lead (Pb)	150?	32	170?	99	160?	37	89	51	123?	42	111?	31	26			100	100-200	200
Zinc (Zn)	235?	51	274?	119	236?	59	124	60	123	53	146	38	40			200	200-400	400
Cadmium (Cd)	7.2?	2.9	4.5	2.4	2.2	1.8	3.1	2.6	3.7	1.4	2.5	3.1	2.1			5	5-10	10
Chromium (Cr)	72	36	63	44	80	32	43	30	74	25	53	27	7.9			100	100-300	300
Copper (Cu)	157	24	159	55	150	46	77	34	110	21	80	23	26			200	200-400	400
Nickel (Ni)	36	24	34	59?	32	27	21	26	61?	21	27	23	16			50	50-100	100
Vanadium (V)	96?	48	91?	85?	85?	73	47	34	74	56	71	61	42			75	75-125	125
Arsenic (As)	6.0	0.3	6.8	1.6	6.4?	0.4	3.9	0.3	4.2	2.8	3.5	0.6	1.2			10	10-20	20
Suggested Classification	III	II	III	II	III	III	II	II	III	II	II	II	I					

APPENDIX B

In November 1978, the Army Corps of Engineers resampled the sediments within Pawtuxet Cove as part of the navigation maintenance and proposed marsh establishment project at Rock Island. Sediments from within the dredging source area as well as the disposal area were sampled to determine contaminant levels, grain size, etc. The following tables present the pertinent results of these analyses and, as in the tables in Appendix A, gives the authors' suggested classification of the sediment samples. These results can be compared to the previous Corps samples of Pawtuxet Cove taken in 1975 (see Appendix A). It is evident from both analyses that while Pawtuxet Cove does contain significant levels of contaminated sediments, pollutant levels decline substantially in the South Cove and in other sections some distance from the Pawtuxet River mouth. Also, it is interesting to note that some samples within the area to be dredged contain lower levels of contaminants than the samples in the designated disposal site.

AREA LOCATION: Pawtuxet Cove (Dredging Area) 11/20/78

Sediment Core #	GEB-1-78	GEB-2-78	GEB-3-78	Conn. Sediment Class levels I	II (?)	III (*)
Sample Depth (Ft.)	surface	surface	surface			
Sounding (Ft.)	6.2	9.0	5.5			
	entrance	south cove	north cove			
% Silt /Clay	14.6	21.4	80.5?	60	60-90	90
Sample Depth (Ft.)	surf.	surf.	surf.			
% Solids	72.25	74.59	28.32*	60	60-40	40
% Volatile Solids	1.66	1.06	13.18*	5	5-10	10
Hexane Soluble Fraction (ppt.)	1.52	0.98	17.3*	5	5-10	10
Metals (ppm)						
Mercury (Hg)	0.17	0.16	1.4?	.5	.5-1.5	1.5
Lead (Pb)	94.1	21.5	466.1*	100	100-200	200
Zinc (Zn)	152.2	64.4	819.2*	200	200-400	400
Cadmium (Cd)	0.5	0.5	5.6?	5	5-10	10
Chromium (Cr)	66.4	21.5	197.7?	100	100-300	300
Copper (Cu)	105.2	37.5	494.4*	200	200-400	400
Nickel (Ni)	22.1	10.0	127.1*	50	50-100	100
Vanadium (V)	11.1	10.0	70.6	75	75-125	125
Arsenic (As)	1.1	2.2	12.2?	10	10-20	20
Suggested Classification	I	I	III			

AREA LOCATION: Pawtuxet Cove (Proposed Disposal Area) 11/20/78

Sediment Core #	PE-1-78	PE-2-78	PE-3-78	PE-4-78	Conn. Sediment Class levels I	II (?)	III (*)
Sample Depth (Ft.)	0-2.4	0-2.2	0-1.7	0-2.0			
Sounding (Ft.)	1.9	1.7	2.0	2.1			
% Silt /Clay	89.7?	84.0?	87.5?	79.9?	60	60-90	90
Sample Depth (Ft.)							
% Solids	42.39?	38.67*	48.49?	46.15?	60	60-40	40
% Volatile Solids	5.71?	7.27?	5.34?	5.44?	5	5-10	10
Hexane Soluble Fraction (ppt.)	1.42	5.54?	1.55	3.62	5	5-10	10
Metals (ppm)							
Mercury (Hg)	0.69?	1.5*	0.45	0.64?	.5	.5-1.5	1.5
Lead (Pb)	113.2?	239.9*	98.9	112.7?	100	100-200	200
Zinc (Zn)	245.3?	523.6*	185.6	273.0?	200	200-400	400
Cadmium (Cd)	2.8	4.4	0.5	2.6	5	5-10	10
Chromium (Cr)	160.4?	327.3*	107.7?	164.5?	100	100-300	300
Copper (Cu)	273.6?	763.6*	198.0	320.7?	200	200-400	400
Nickel (Ni)	37.7	87.3?	33.0	52.0?	50	50-100	100
Vanadium (V)	47.2	54.5	66.0	43.3	75	75-125	125
Arsenic (As)	8.0	7.9	6.5	6.0	10	10-20	20
Suggested Classification	II	III	II	II			

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