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Assessment of Clam Resources and Sanitary Quality of the Shellfish Growing Waters in Witch Creek, Seavey Creek and Little Harbor

A Final Report to

The New Hampshire Office of State Planning, New Hampshire Coastal Program

Submitted by

Dr. Stephen H. Jones[1,2] and Dr. Richard Langan[1,3]

[1]Jackson Estuarine Laboratory, University of New Hampshire
[2]Department of Natural Resources, University of New Hampshire
[3]Department of Zoology, University of New Hampshire

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NH OFFICE OF STATE PLANNING COASTAL PROGRAM

Sanitary Survey

for

Little Harbor, Seavey Creek and Witch Creek

New Castle and Rye, New Hampshire

July, 1996

prepared by

Dr. Stephen H. Jones and Dr. Richard Langan
Jackson Estuarine Laboratory
University of New Hampshire
Durham, NH 03824

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I. Executive Summary

Many improvements have been made in wastewater treatment facilities on the Piscataqua River and throughout the Great Bay Estuary, and best management practices for stormwater control and other potential pollution sources have become more prevalent in recent years. The results of the present sanitary survey suggest that some areas could be classified as approved, pending collection and similar results from adequate numbers of samples at all sites. This approved area could include all of Little Harbor and portions of the mouth of Witch Creek and Seavey Creek. A thorough analysis of conditions and water quality in the whole growing area indicates that classification of the area would probably require some meteorological and seasonal-use conditions, the latter because of the prevalence of boats during months (May, September, October) when clamflats could otherwise be open. Relatively heavy rainfall events (>1"/48h) appear to cause significant decreases in water quality. The proximity of the site to areas of coastal New Hampshire where no shellfishing is presently allowed, in addition to the encouraging water quality results, makes this a desirable site for reclassification.

II. Description of Growing Area

A. Location map showing growing area

Figure 1 shows the boundaries of the growing area in question which includes all of Little Harbor out to Jaffrey and Frost Points at the harbor mouth, and extends south through the mudflats at the mouths of Witch and Seavey Creeks. Berry Brook, upstream Witch Creek and the flow from Sagamore Creek/Back Channel area west of the Rt. 1B bridge are considered potential point sources of pollution for the purpose of this study.

B. Description of area

The growing area lies near the northernmost portion of coastal New Hampshire. Specifically, the area is bordered on the north by New Castle Island, to the east by Fort Stark State Historical Site and the Atlantic Ocean, to the south by Odiorne Point State Park and the Witch/Seavey Creek area, and to the west by the Wentworth-by-the-Sea golf course and the Back Channel area. New Castle to the north and Rye to the south and west are the two towns bordering the area. Water movement within the area is governed primarily by tidal currents while minor influences are provided by the few tributaries that carry freshwater into the area. The only tributaries in the area are Berry Brook, Witch and Seavey Creeks and the water flowing into the harbor from the Back Channel area.

Little Harbor and the rest of the survey area constitute a small, shallow embayment with an average depth of ~2 m, with deeper channels extending to 5 m. The deepest waters are confined to one channel that extends from the Rt. 1B/Back Channel out to the mouth of the harbor. The mean tidal range of the growing area is 2.4 m, ranging from 2.1 to 3.4 m. The area is subject to strong tidal currents and vertical mixing, limiting the vertical stratification of waters throughout most of the year. During periods of excessive freshwater runoff, partial stratification of the water column can occur. A large portion of the area is exposed at low tide with most of the intertidal zone consisting of mudflats and some macrophyte and rocky habitats. Extensive salt marshes exist around the upper intertidal zones at the mouths of Seavey Creek.

Several bivalve species can be found within the growing area including blue mussels (*Mytilus edulis*), soft shell clams (*Mya arenaria*) and a few American oysters (*Crassostrea virginica*). Soft shell clam habitat is prevalent, with a harvestable area of approximately 35 acres, but the abundance is generally low (see Appendix A). Blue mussels are dominant in many of the low intertidal and subtidal (channel) areas in high abundance, probably constituting the dominant standing shellfish stock in the area.

The shorelines of the survey area are a mix of residential property, protected lands and woodlands. Most of the land surrounding the watershed for the growing area is forested.

Agricultural use of shoreline land within the growing area is essentially nonexistent. Human population along the growing area is moderate, with concentrated areas along the southwestern shore around Wentworth and Pioneer Rds. in Rye, the Wentworth condominiums on the northern shoreline, and a moderately dense area on the northeastern shoreline in New Castle. Shoreline ownership around the growing area is typically private, with a golf course and some lands protected or in government ownership. Two state-owned areas border the growing area. One is Odiorne State Park, a large area which dominates the southeastern shoreline. On Jaffrey Point on the north shore of the mouth of the harbor is Fort Stark State Historical Site.

C. History of growing area classification

The survey area has been classified as prohibited since the late 1980's when the Wentworth-by-the-Sea marina was expanded. The last comprehensive sanitary survey conducted in the area took place many years ago. The water quality in Little Harbor and the Back Channel was seriously degraded by the primary effluent from the Portsmouth wastewater treatment plant (WWTP) prior to its being upgraded (NHFG, 1991). Since that time, the WWTP has been rebuilt and poses only a rare threat to water quality. One remaining combined sewer overflow (CSO) in South Mill Pond is still of concern. Significant new construction has occurred as part of the Wentworth-by-the-Sea marina/condominium expansion, although all septic wastes are discharged into a sewer system and pumped to the Portsmouth WWTP. Numerous non-sewered residences in Rye and New Castle have replaced failed septic systems and overboard discharges.

The potential for clam harvesting in the area is substantial based on the acreage of potential clam flats. According to the NHFG (1991), there are 400 acres of clam flats in the Little Harbor and Back Bay area, compared to 162 acres in Hampton/Seabrook Harbor and 500 acres in Great Bay. The flats were not thought to be as productive as Hampton/Seabrook Harbor, which had an estimated standing crop of ~8x that of the Little Harbor area. An update of the clam resources in Little Harbor and the Seavey/Witch Creek area has been conducted as part of this project, and the results are presented in Appendix A. In addition to significant potential habitat area, recent water quality results determined by NHDPHS suggest that the area may be one of the most likely areas for consideration to be re-opened (see Section V).

III. Pollution Source Survey

A. Summary of Sources and Locations

<u>1. Map or chart showing the location of major sources of pollution</u>

Figure 2 shows the locations of potential pollution sources to the growing area. A discussion concerning each individual source follows in Section 2.

<u>2. Table of pollution sources</u>

Table 1 lists six actual or potential pollution sources found either directly within the growing area or that could influence the quality of water which flow into the growing area (Figure 2). Included in Table 1 are "Relevant Sample Sites." These are specific water quality sampling sites that have been designated to show the effects, if any, that each pollution source listed in Table 1 has on a specific section of the growing area. Table 2 lists all of the routine sampling sites established for the survey area. Figure 3 shows all routine sampling sites which have been established in order to monitor water quality throughout the growing area. Sites T1, T5, T6, T8, T9, T10, and T13 are sites established by DPHS to support the routine classification of the area. Sites T7 and T14 are routine sites reactivated this year, and WC1 and LH2 are new sites added this year. Sites T1, T6, T13, T14 and LH2 are located in the potential growing area and sites T5, T7, T8, T9, T10 and WC1 are in areas that may influence the water quality of the growing area. Data for all of these sites are presented in Table 3 for DPHS analyses and Table 4 for JEL analyses, and discussed in Sections IV, V and VI.

The water quality in all tributaries have been evaluated. These include Berry Brook, Witch and Seavey Creeks, and the Back Channel, all of which are being treated as individual point sources of pollution. Figure 4 shows the small tributary sampling sites,WC 2, 5 and 6, PC 1, 2, 4 and 5, SC 1 and 2, and WRL1; the analytical results are presented in Table 5. All of the tributary samples showed little contamination, with a decrease going downstream. None of these tributaries appear to have much impact on water quality in Little Harbor, based on the results for the routine sample sites T6 and T14 (Tables 3 and 4).

Pollution sources listed in Table 1 and below which are located on the major river tributaries are considered to be either point or non-point sources within these tributaries. A brief explanation of each source and its potential to contaminate the growing area is given below.

PS1, PS2 -The Wentworth-by-the-Sea marina/condominium complex has a potential for contamination via two mechanisms: PS1-direct discharges from boats docked at the marina, and PS2-from the stormwater drainage system around the condominiums. There are 170 slips for boats at the marina, 4 of which are reserved for transient boats and the rest are individually reserved. From mid- to late-May through early- to mid-October, the slips are essentially fully utilized. The pump-out facility is a nine year old Keco vacuum system with a 1.5" pipe through which waste is pumped to the town's sewer system. The facility has had heavy use, and may need to be replaced in the near future to insure that such a well-functioning facility in such a key area is capable of handling the high demand. The marina is essentially unused during the rest of the year. Thus, the potential for pollution from the marina is a highly seasonal factor.

Stormwater from the condominium area flows through two vegetated swales designed to detain and decontaminate stormwater. These systems appear to receive lightly contaminated water (see Section III.B.3). The marina and stormwater sources are potential direct sources.

PS3- There are ~100 boat moorings located within and to the north of the main channel near the middle of Little Harbor. Approximately 60 of the 100 moorings are used by members of the marina, and they all routinely use the marina pump-out facility. Some of the other boats also use the facility. Like the marina, these moorings are used from May to October, and virtually not at all the rest of the year. Thus, the potential for pollution from the mooring field is highly seasonal. This source is a potential direct source.

PS4- The Wentworth-by-the-Sea golf course is an eighteen hole course that lies directly on the southwestern shoreline of the harbor. The buildings are distant from the shoreline, but there is fertilizer and pesticides applied to the fairways and greens (see Section III.B.4). These apparently have little impact on the water quality of the adjacent portions of the harbor, even though they are considered potential direct sources.

PS5- The Portsmouth wastewater treatment plant is located on Pierces Island along the southern portion of the Piscataqua River. The effluent discharge pipe is located in the main river channel near to the main entrance to the Back Channel. Any malfunction in plant operation that would lead to discharge of untreated sewage could impact the survey area via water flow through the Back Channel. This source is considered a potential, indirect pollution source.

PS6- There is one combined sewer overflow in Portsmouth that is located in South Mill Pond. Untreated sewage may be discharged through this source, especially during high volume rainstorms. The concern is that contaminated water flowing out of South Mill Pond could enter Little Harbor via flow through the Back Channel. This source is considered a potential, indirect pollution source.

B. Identification and evaluation of pollution sources

1. Shoreline Survey

The shoreline survey was conducted by boat at both low and high tide in August, 1995 and May, 1996, and by foot in populated areas during April and May, 1996. Properties were surveyed at high tide by boat to gain close access to shore for better observation. Walking along the shoreline at low tide, any pipes located below the high water mark could be more readily observed. Homes bordering the growing area were evaluated by looking for malfunctioning septic systems, gray water pipes, outhouses and other potential pollution sources. All drainage streams with flowing water were sampled and water samples analyzed.

No apparent pollution sources were observed at high tide in the boat. The areas covered by the low tide shoreline reconnaissance included Pioneer Rd. west of the Rt. 1A bridge, Brackett Rd. near the Berry Brook bridge, the Foyes Rd./Frontier St. area, and the Wentworth Rd. area to the northwest of the golf course. No obvious failed septic systems, outhouses or flowing drain pipes were seen. Numerous ditches that drained into the tidal waters and originated in back lots and small streams that flowed close to shoreline houses were sampled during the springtime when water tables were elevated. These were mostly located around Pioneer Rd. as illustrated in Figure 4. The results of the water analyses (Table 5) showed little contamination was associated with these ditches and streams, suggesting that septic systems for shoreline homes were not contaminating the drainage streams that empty into the tidal waters.

2. Domestic wastes

A. Septic systems

Towns abutting the growing area with residences on septic systems are New Castle and Rye. The most densely populated areas are New Castle Ave. (Rt. 1B) and Pioneer Rd. (Rt. 1A) in Rye. These homes are all essentially year-round residences. The northern shore of Little Harbor in New Castle is a moderately populated area. Research was carried out at each town hall to obtain septic system information for each residence within 500 feet from shore (see Appendix B). Locations of homes are given by map and lot number for each town according to the town tax maps (also Appendix B). All homes in areas surrounding the growing area have individual septic systems with the exception of the Wentworth condominiums and marina which are linked to Portsmouth's municipal sewer system. A complex pattern of other homes in New Castle are also linked into the Portsmouth sewer system. Soil suitability for septic tanks along the growing area shores varies, with poorly and very poorly drained soils dominating in and around the salt marsh area at the mouth of Seavey Creek and a freshwater marsh behind the northeast shoreline of Little Harbor. In addition, some of the soils on land adjacent to Witch Creek and other scattered area are also unsuitable for development/septic systems.

B. Wastewater treatment plants

There are no municipal wastewater treatment plants which discharge directly into the growing area, although one discharges into the nearby Piscataqua River (PS5; Figure 2). Thus, the Portsmouth WWTP may indirectly impact the growing area due to its nearby location. Portsmouth rebuilt their entire primary plant, completed in 1992, under a DES/EPA Consent Decree. It is an advanced primary treatment system with sand filters, primary settling clarifiers, and chlorination that serves essentially the entire city of Portsmouth and parts of New Castle. The effluent discharge pipe is located approximately 300 feet off shore from Pierces Island near the middle of the river channel. Sand filters and dechlorination were added to ensure adequate disinfection and minimize discharge of chlorinated compounds. The Consent Decree was terminated after the facility demonstrated twelve continuous months of meeting the bacterial limit of 70 total coliform/100 ml.

No industrial waste is processed in the plant. Design flow is for an average flow of 4.7 mgd and a hydraulic peak flow of 22 mgd. The average flow during the past year was 5.3 mgd. The system is alarmed for both power failure and high water flow. There are 17 pump stations, all alarmed. There are an additional 3 pump stations in New Castle. One CSO still receives untreated wastewater, and discharges to South Mill Pond. Recent efforts have been made to upgrade sewer lines throughout the city, including South and North Mill Ponds. Pump houses have also been upgraded.

3. Marinas

During the period from mid-May through mid-October, the Little Harbor portion of the study area experiences heavy recreational boating activity consisting of power and sailing vessels of all sizes. In addition, there is a 170 slip marina and a mooring field with 100 moorings. By mid-October, the vessel traffic is negligible and the vessel that occupy the marina slips and moorings during the boating season are either hauled out of the water or winterized and idle at the marina slips.

Since illegal discharge of human wastes from vessels poses a potential human health threat for shellfishing waters, a prohibited shellfishing area must be established if the potential for illegal discharge exists. The Wentworth Marina has a sewage pump-out facility that services all the vessels at the marina and ~60 vessels that occupy the moorings. Their facility is easily accessible at the fuel docks, and discharges directly to a sewage pipe that connects with Portsmouth WWTP. Sean McKenna, the marina manager, reports that the facility is heavily used.

In determining a worst case scenario of events for establishing a prohibited zone, it is assumed that two people would be discharging wastes per boat per day, each individual producing 2×10^9 fecal coliforms (FC). If it is assumed that all vessels at the marina discharged wastes on a daily basis this would produce $170 \times 2 \times 2 \times 10^9$ or 680×10^9 FC into the waters surrounding the marina. The total volume of water at the marina area at low tide is 8.8×10^8 liters, or 88×10^8 100 ml units. If complete mixing is assumed, the resulting concentration would be 77 FC per 100 ml. The water within the marina slips is quite still, and mixes with channel waters after slowly moving toward the channel on the ebb tide. All vessels discharging in one day is an unlikely scenario, just as complete mixing of wastes with the surrounding water is unrealistic. If instead we assume the 10% or 17 vessels discharge $17 \times 2 \times 2 \times 10^9$ FC daily, and that the discharge mixes only with the upper 0.5 m of the water column, the resulting concentration of the surface waters within the marina area would be 116 FC per 100 ml. The plume would eventually mix with channel waters and would be transported toward the Wentworth clamflat on a falling tide, and toward the triangle flat on a rising tide. If the plume mixes with an equal volume of water as it joins the channel flow, then water with a concentration in excess of the 14 FC/100 ml could reach the two flats, therefore placing them in the prohibited safety zone.

The mooring field also may pose a potential risk from discharge. If it is assumed that 10% of the moored vessels discharge each day, then 10 vessels x 2 persons $\times 2 \times 10^9$ FC = 40×10^9 FC would be discharged into an area with a volume of 6.3×10^8 100 liter units, the resulting plume concentration would be 66 FC/ 100 ml in the mooring area. If the plume mixes with an equal volume of flood tide waters water with a concentration 14 FC/100 ml would be transported in the direction of the triangle flat, and potentially the Odiorne, Seavey and Berry Brook flats. The plume mixing with ebb tide waters would not likely impact any of the flats in the growing area.

An additional source of contamination which would be very difficult to quantify is waste discharge from the transient boat traffic in the area. As previously mentioned, vessel traffic is very heavy in the area from mid-May through mid-October. Numbers, sizes, and length of time vessels spend in the area, along with estimates of waste volumes discharged, would have to be included in the equation in order to estimate the volume of sewage discharge.

4. Stormwater

There are two potentially significant stormwater sources that could impact the water quality of Little Harbor. One is the drainage from the new Wentworth-by-the-Sea condominium/marina complex on the northern shoreline of the survey area, and the other is the CSO in Portsmouth (PS2 and PS6; Figure 2). Portsmouth has eliminated nine of ten CSOs, but one remains in South Mill Pond. The concern for the Little Harbor area is that contaminants flushed into South MIll Pond from the CSO could flow through the Back Channel area into Little Harbor (NHDES, 1995). Elimination of the remaining CSO would cost an estimated $10 million, as estimated by the city's CSO Facility Plan. Because of the high costs associated with elimination of the CSO, the City of Portsmouth has filed for a Use Attainability (UAA) Study to reclassify the receiving waters, i.e., South Mill Pond. If they are successful in proving that the costs are essentially prohibitive, then they would not be required to attain the limit of 70 total coliforms per 100 ml in South Mill Pond. In such a case, careful attention to the potential for storm-related contamination to affect any opened shellfish beds in Little Harbor would be necessary. It would also be difficult to open the extensive mudflats in the Back Bay area.

The other potential source of stormwater is the drainage system of the condominium-marina complex at Wentworth-by-the-Sea. There are two vegetated swales in that area that are designed for control of stormwater from impervious surfaces. The major swale, located next to the marina parking lot, has been studied as part of a joint NHDES/UNH-JEL study over the past year. Water samples were collected during the initial 0.5" of rainfall of three storm events in 1996 at the influent pipe and the effluent drain to determine if the swale is effectively treating stormwater. Fecal coliform levels were relatively low in all samples, ranging from 2 to 56/100 ml (unpublished data). It appears that the drainage swales are not receiving stormwater with any significant contamination, and the stormwater from the Wentworth complex probably has little effect on harbor water quality.

There are some other potential indirect sources of contamination to Little Harbor located in Portsmouth. There are some storm and parking lot drains in the city that drain into the tidal waters, although none that would have much impact on Little Harbor. There are also three snow dump sites on the southern end of town, two on Pierces Island and one next to South Mill Pond.

5. Agricultural waste and golf course fertilizer applications

Agricultural use of land within the growing area has greatly declined during the past fifty years. At present, there are no working farms along the shoreline of the growing area. However, the Wentworth-by-the-Sea golf course (PS4; Figure 2) uses both fertilizers and pesticides. A slow-release fertilizer (24-4-12) is applied to fairways, tees and greens in May, June and September at annual rates ranging from 130-218 lbs/acre of nitrogen and 22-36 lbs/care phosphorus. Roughs are not fertilized. Grass clippings are returned directly (mulched) onto fairways. Tee and green clippings are collected and spread on the roughs. Water samples collected at sites along the shoreline of the golf course were analyzed for dissolved inorganic nutrients. The results (Table 6) show low concentrations of nitrogen and phosphorus, suggesting that the fertilizers applied at the course have little impact on the water quality of the harbor.

Insecticides are not used routinely on a large scale. An integrated pest management system is employed and pesticide application is limited to spot application to control grub infestation. Preventative treatment for snow mold fungus is applied only to tees and greens. Heavy metal (mercury) based compounds are not used. All materials are applied conservatively with particular caution paid to adjacent surface waters and wetland buffer zones. Equipment used for applications is field-rinsed, and the diluted rinse water is sprayed onto the fairways to prevent a large volume of this water being washed into maintenance facility storm drains (Rye-Wentworth Impact Assessment Report, 1990).

6. Wildlife areas

There are two areas where wildlife may be prevalent within the growing area. One is Odiorne State Park, and the other is the extensive salt marshes of Seavey Creek and Berry Brook, part of which is owned and managed by Odiorne State Park. Habitat areas in Little Harbor have been mapped (Figure 5).

Mammals living within the growing area include whitetail deer, beaver, fox, mink, otter, muskrat, squirrels, chipmunks, rabbits, moles, voles, rats, mice, bats, shrews, weasels, skunks and raccoons (Seacoast Science Center, 1992). Wildlife populations are not suspected to be large enough to impact water quality, especially considering that most of the shoreline is developed. In addition, the Little Harbor area is a seasonal stopover for many waterfowl and wading birds. Species commonly seen or heard during one or more seasons include common loon, grebes, cormorants,bittern, brant, Canada geese, mallard, eider, oldsquaw, scoters, common goldeneye, bufflehead, mergansers, hawks, kestrel, plovers, killdeer, yellowlegs, willet, sandpipers, godwits, turnstone, dunlin, snipe, gulls, terns, dovekie, owls, whip-poor-will, swift, kingfisher, woodpeckers, flicker,flycatchers, phoebe, kingbird, swallows, jays, crows, chickadee, nuthatches, wrens, kinglets, wheatear thrushes, robin, catbird, mockingbird, cedar waxwing, starling, vireos, warblers, parula, warblers, redstar, yellowthroat, grosbeak, towhee, sparrows blackbird, grackle, orioles, finches, crossbill, goldfinch, and a large variety of less common birds. Quantitative assessments of birds, waterfowl and wildlife populations are not available so it is not known what effect they may have on water quality in the growing area.

7. Industrial waste

There are no industrial activities on the shores of the survey area. Small scale, light manufacturing is practiced in Portsmouth and along the Piscataqua River, well outside of the growing area. However, the Portsmouth Naval Shipyard, located in Kittery directly across the river from the mouth of the Back Channel, has been the site of significant historical storage and use of toxic contaminants. An environmental assessment of the shipyard and surrounding estuarine habitats has shown some elevated levels of some toxic compounds in depositional areas and some biota (USEPA/NCCOSC, 1994). Little evidence of actual toxic effects on biota was apparent.

The Coakley Landfill is located in North Hampton 6 miles up the freshwater portion of Berry Brook. It received municipal and industrial wastes from the Portsmouth and Pease Air Force Base area between 1972-1985. In 1983, the NHDES found groundwater and surface water contamination with volatile organic compounds (VOCs) at numerous sites in the area (see Hughes and Brown, 1995). The site was added to the USEPA National Priority List in 1983, ranked number 680. The site has undergone remediation, yet VOCs are still being detected in some locations near the landfill (1993 EPA data). This became a concern of the Town of Rye, and they undertook a small investigation of water quality along the whole length of Berry Brook. They sampled twice during the spring of 1995, and had samples from 9 sites along the stream, from the Coakley Landfill to the estuary, analyzed for a wide range of contaminants (Hughes and Brown, 1995). These included 10 metals, 60 VOCs, 20 pesticides and 7 PCBs. None of the toxic organic compounds were detected in any sample. The metals were all present at low concentrations or undetectable. They found dissolved oxygen to be low near the landfill, but satisfactory at other sites. Suspended solids, dissolved inorganic nitrogen and phosphorus, and fecal indicator bacteria concentrations were all low.

The Little Harbor and the Great Bay/Piscataqua River Estuary areas have been subject to significant historical industrial contamination, and the prevalence of urban areas along the shorelines poses potential continued nonpoint source pollution by toxic compounds. The Gulf of Maine Council on the Marine Environment has conducted a musselwatch monitoring program, called Gulfwatch, at sites throughout the Gulf of Maine for the last 5 years (GOMCME, 1992; 1994; in press). Short- and long-term exposure of mussels to toxic inorganic and organic contaminants have been determined at sites that include Little Harbor and some nearby sites like Shapleigh Island in the Back Channel, Odiorne Point, and Clark Cove on Seavey Island (Figure 4). Contaminant concentrations in tissue samples from mussels collected at these sites are summarized in Table 7, along with FDA "edible portion" limits. Also included are tissue concentrations for mussels collected from the same sites as part of the Portsmouth Naval Shipyard assessment (USEPA/NCCOSC, 1994) during approximately the same time frame for comparison. Sample results from Brave Boat Harbor and Hampton Harbor are also included as reference sites where there are few or no known contamination sources. None of the tissue concentrations for mussels from Little Harbor during 1991 and 1992 were above the FDA guideline levels. Lead and mercury concentrations were somewhat elevated and closest to FDA guideline levels. This is consistent with known historical contamination in the area. The metal concentrations are similar to levels found at Shapleigh Island and Clark Cove, and somewhat higher than concentrations at the two reference sites at Brave Boat Harbor and Hampton Harbor. For organic compounds, Little Harbor tissue concentrations were lower than those at Shapleigh I. and Clark Cove, and higher than those at Odiorne Pt., Hampton Harbor and Brave Boat Harbor. Overall, none of the sites have higher levels of contaminants that would indicate close proximity to a source of contamination. The levels at Little Harbor were somewhat higher than the 'reference' sites. However, comparison of levels at those 'reference' sites to other sites in the Gulf of Maine covered by Gulfwatch and by the National Status and Trends Musselwatch Project, as well as other sites throughout the U.S (Gottholm and Turgeon, 1992) indicates that these sites are not true reference sites because other sites have much lower levels of contaminants. Gottholm and Turgeon (1992) found mussels from the Great Bay Estuary to have Hg and Pb levels well above the 50th percentile level for all sites in the NS&T project. There were a number of sites from the Gulf of Maine that also grouped higher than the 50th percentile level, essentially all of which were located in New Hampshire and southward, i.e., nearest to the large urban population center of Boston. This suggests that the whole area is exposed to somewhat elevated levels of contaminants, with no contaminants present in Little Harbor at levels above critical limits.

IV. Hydrographic and Meteorological Characteristics

A. Tides: Type and circulation

The study area experiences diurnal tides. Mean tidal height is 2.4 m and ranges from 2.09 m to 3.36 m depending on celestial configuration. There is one entrance to the Harbor located between Frost Point to the south and Jaffrey Point to the north. The channel mouth is 230 m wide, being constricted by jetties at both the northern and southern sides. The harbor entrance faces southeast due to the positioning of the jetties. The primary source of freshwater discharge into the study area is from Berrys Brook, while lesser amounts of freshwater enter the area from Witch Creek and Seavey Creek. However, the latter two primarily drain tidal wetlands and have relatively small watersheds. Additional freshwater can enter the study area via Sagamore Creek and the Back Bay Area of the Piscataqua River. Sagamore Creek also primarily drains tidal wetlands while the waters of the Back Bay are composed of mixed estuarine discharge from the Piscataqua/Great Bay Estuary. Average water volume in the study area was calculated from bathymetric charts to be 8.7×10^5 m^3 at low tide and 19.93×10^5 m^3 at high tide. Partial stratification may occur in the study area during time of heavy rainfall and runoff. The stratification is generally short lived, since watershed areas that drain into Little Harbor are relatively small. Vertical profiles of temperature and salinity were measured at six stations during ebb and flood tides in May of 1996. Rainfall and runoff during the period preceding the measurements was greater than average. A spatial salinity gradient was found throughout all stages of the tide on sampling days with the greatest differential of nearly 10 ppt measured at low slack tide between the station at the Pioneer Road Bridge to the Harbor Mouth. With the exception of the Pioneer Road Bridge station and Sheafes Point, temporal salinity changes were small throughout the tidal cycle for all stations. Vertical profiles (Table 8) indicate that the channels are vertically well mixed. The greatest differential in salinity (4 ppt in 4 meters) occurred at the Harbor mouth station at the early stages of the flood tide when the denser oceanic water was flowing in at depth and the less saline waters were still flowing out on the surface. The smallest vertical differential occurred at the Rte 1 B Bridge channel and the Pioneer Road Bridge stations.

Surface tidal velocity and direction was measured at six stations in the study area on both flood and ebb tides. Stations were chosen to represent either the most important points of inflow and outflow as well as the location of potential pollution sources. The location of velocity and direction measurement stations appear in Figure 6 and data is presented in Table 9. Though tidal velocity will approach zero at the time of slack ebb and flood, the values presented in Table 9 represent the minimum velocities measured during the study. Greatest current velocities were measured at the channel under the Rte 1B bridge. Ebb velocities were slightly greater than flood and ranged from 7 to 120 cm/s with an average of 80 cm/s on the ebb and 75 cm/s on flooding tide. Flow in the study area appears to be dominated by this channel in addition to the net inward and outward flow of water through the Harbor entrance.

Tidal currents at the remaining stations ranged from 2 to 55 cm/s. The average velocities (in cm/s) were similar at the Harbor Mouth (27 Flood, 30 ebb), the center of the mooring field (20 flood, 23 ebb), Sheafes Point (19 flood, 25 ebb), and the Pioneer Road Bridge (20 flood, 28 ebb) the Wentworth Marine fuel dock (25 flood, 30 ebb). The direction of flow in the channels generally followed the configuration of the channels. There is a lag time of approximately 45 minutes between slack low water from the harbor mouth to the bridge at Pioneer Road.

Though not established as a measurement station, ebb current flow was measured at the center of the boat slip area at the Wentworth Marina. The pattern of flow is generally a slow (< 8 cm/s) outward movement of water in a direction perpendicular to the shoreline until the water mass reaches the outside areas of the floating docks. As the water reaches the main ebb flow and mixes with the channel waters, it the velocity increases rapidly and flows in a northeasterly direction toward the channel mouth.

B. Rainfall: Amounts, seasonality and frequency of significant rainfalls

Listed below are monthly and yearly total inches of rainfall from January, 1993 to June, 1996. Rain gauge measurements from Durham, NH, were obtained from Dr. Barry Keim and Robert Adams, the present and former NH State Climatologists. The frequency of rainfall events ≥0.5"/48 h are noted in parentheses.

	1993	**1994**	**1995**	**1996**
January	1.62(1)	4.88(5)	4.45(4)	2.74(2)
February	2.77(3)	1.60(1)	2.76(3)	1.59(1)
March	4.63(3)	5.46(4)	1.87(1)	2.49(4)
April	4.80(7)	2.76(2)	1.85(1)	6.64(6)
May	0.73(0)	4.02(4)	2.74(3)	3.64(3)
June	2.44(1)	1.73(1)	1.92(1)	1.86(1)
July	1.49(1)	2.20(1)	3.79(3)	
August	2.21(3)	4.05(3)	2.72(2)	
September	4.19(5)	7.26(3)	2.79(3)	
October	3.08(3)	0.19(0)	6.53(4)	
November	3.81(4)	2.88(2)	7.41(4)	
December	5.58(3)	5.55(3)	2.46(2)	
Yearly total	37.35(34)	42.61(29)	41.29(31)	18.96(17)
Yearly mean	33.11 (2.8)	3.55 (2.4)	3.44 (2.6)	3.16(2.8)

Overall mean monthly rainfall: 3.34", with 2.6 rainfall events/month >0.5"/48 h

Monthly precipitation ranged from 0.19 inches in October, 1994, to 7.41 inches in November, 1995. There were a total of 111 1-2 day rainfall events with >0.5" rain in 48 h. These events were relatively evenly distributed during the months when shellfish could be harvested

(September-June). The sampling (29 samples) conducted for water quality monitoring by DPHS included 1 of these 111 events and auxiliary sampling (11 samples) by JEL included 2 of the 35 such events that occurred during the study period.

C. Winds

Winds affecting the growing area tend to come from the north and northwest in the fall and winter months and from the southwest during spring and summer months. Northeasterly winds are typical of storms. Wind-driven waves can greatly affect current direction and speed, especially in the shallower areas of Little Harbor. Northeast winds tend to restrict ebb currents, holding water in the harbor, while southwest winds restrict flood currents from flowing into some of the southern portion of the growing area. Wind waves may influence grain-size distributions and sediment transport within the growing area. Current velocities at the sediment surface can become greater than tidal current velocities as a result of wind waves, especially in the shallower areas of the growing area where overall tidal current strength tends to be low. In general, the effects of tidal currents throughout the area may at times be significantly modified by wind-driven currents.

Wind waves that influence the bottom can also resuspend sediments, increasing turbidity levels and particle-associated contaminants above those produced by regular tidal currents alone. Surface sediment samples were collected from seven sites around the harbor in May, 1996 to determine the potential for sediment-associated bacteria to influence water quality by resuspension during wind events. The seven sites were along a transect extending from the southern upper harbor area in Seavey Creek out through the harbor to the flat along the north shoreline near the mouth (SS1-6; Figure 4). The data are presented in Table 10 and illustrated in Figure 7. Concentrations of sediment-associated fecal coliforms and *C. perfringens* increased from the Seavey Creek (SS1) flat out to the Triangle Flat (SS5 A&B) near the Rt. 1B bridge, then decreased to the lowest levels tested in the Wentworth flat (SS6) near the harbor mouth. Levels of fecal coliforms ranged from 3/100 g dry sediment at the Wentworth Flat to 218/100 g at the Triangle Flat. Whereas these levels are relatively low, their spatial distribution suggests that recent fecal-borne bacteria accumulate in the sediments, especially around the Triangle Flat. The *C. perfringens* data illustrate long-term accumulation of fecal-borne bacteria. The concentrations ranged from 1990/100 g at the Wentworth Flat to 318,000/100 g at the Triangle Flat. The relationship between fecal coliform and *C. perfringens* levels was relatively close, with a correlation coefficient of $r^2=0.74$ ($P=0.06$). The similar spatial pattern for concentrations of both indicators supports the observation that fecal-borne contaminants apparently accumulate in the sediments, especially around the Triangle Flat.

Significant wind events coupled with the right currents could cause resuspension of the sediments at depositional areas like Triangle Flat and result in elevated contaminants in the water column of other parts of the survey area, with potential contamination of shellfish. The relationship between fecal coliforms in sediments and in soft shell clams was determined at five of the seven sites, using the May, 1996 sediment data and clam tissue data from August/September, 1995 (Table 10). Figure 8 shows the relative concentrations of fecal coliforms along a transect of sites from Seavey Creek to Wentworth Flat near the mouth of the harbor. The relative levels of fecal coliforms in shellfish are higher than in the sediment, reflected in the different y-axis units in Figure 8. The spatial trends for both media are similar, illustrated by the significant correlation coefficient for paired fecal coliform data of $r^2=0.95$ ($P=0.01$). This suggests that the Triangle Flat area is an area where fecal-borne bacteria accumulate and can be taken up by clams in the sediments. It is not known if the clam tissue levels are influenced by sediment-associated bacteria or if the bacteria are taken directly from elevated levels in the water column in the Triangle Flat area and accumulated. However, relatively low levels of FC have been detected in water from the channel under the bridge, suggesting that either uptake from the water column is not the mechanism, that there is no relationship in FC levels between clam tissue and water, or that water sampling was timed such that elevated levels of FC were not detected. The clams were sampled on days that had followed dry weather, suggesting that elevated levels were not associated with stormwater during recent rainfall events. Blue mussels from near the Rt. 1B bridge across the channel from the Triangle Flat also had relatively elevated levels (3000/100 g) of fecal coliforms (Table 10). However, they were sampled on 8/7/95 following 2.42" of rainfall during the previous 4 days. Even though the FC in water in the channel on that day were low (20/100 ml), it is likely that the elevated levels in the epibenthic mussels may have been caused by contaminants in stormwater that had accumulated during the previous days.

D. River Discharges: Volumes and seasonality

There are no major tributaries that empty into Little Harbor. The largest tributary is Berry Brook in Rye, which flows into the Harbor on the southern boundary along with the smaller Seavey and Witch Creeks. Sagamore Creek is an extensive tidal creek that flows into the Back Channel area just to the west of the Rt. 1B bridge. Most of the non-oceanic water that flows into Little Harbor enters through the channel below the Rt. 1 bridge, so Sagamore Creek could potentially influence water quality in the Harbor. All of these tributaries exhibit increased flow in the springtime with snowmelt and the elevated water table conditions associated with the frequent spring rains that occur.

E. Actual or Potential Effects of Transport on Pollution to the Harvest Area

With the recent upgrading of the Portsmouth WWTP, there is only one remaining significant potential point sources of fecal contamination in coastal NH (NHDES, 1994). This is the CSO in Portsmouth that discharges to South Mill Pond which outlets to the Piscataqua River. When significant rainfall events occur, the CSO can overflow and untreated sewage combined with stormwater can potentially contaminate the Back Channel area, which could influence water quality in Little Harbor. The conditions for this to happen have not been studied, so the potential for contamination of the area being classified in Little Harbor by contaminants from the CSO is hypothetical at present.

Nonpoint source pollution is probably the major source of fecal contamination to the classified area. Nonpoint source pollution could enter the area as either urban runoff, stormwater, shoreline development, on-site septic systems, wildlife, boats, or golf course runoff. Stream flow from tributaries entering the area carries some of the annual precipitation to the tidal waters. The less saline water of the tributaries is well mixed within the water column and diluted upon entering the respective harbor and tidal tributaries. Figure 9 shows levels of FC in water along three transects from three areas with tributaries at their upper reaches. In Witch Creek and Berrys Brook/Seavey Creek, the relatively high FC levels upstream in the tidal portion appear to have little influence on water quality downstream. The extremely small freshwater stream at the head of Pioneer Cove has low levels of FC, and does not contaminate downstream waters.

Elevated FC levels may result from contaminated stormwater associated with significant rainfall events. The impact of one storm event (2.68" rain in 24 h) on November 15, 1995 on FC concentrations in the classified area can be seen in Table 2. This storm followed two other storms >0.5" rainfall during the previous week. FC values were significantly elevated throughout the area, ranging from 105/100 ml at the mouth of the harbor to 3350/100 ml in Witch Creek. The next highest levels were found in the other tributaries, including Seavey Creek, Berry Brook and the Back Channel water entering under the bridge. Samples collected on 11/28/95 by DPHS after only 0.47" of rain had fallen in the following 13 day period had much lower levels, ranging from 4.5/100 ml at the harbor mouth to 23/100 ml in Witch Creek. These data suggest that rainfall events can cause elevated levels of contaminants to enter the classified area from the tributaries, and these contaminants are eventually attenuated throughout the area during ensuing dry weather.

Transport of fecal-borne contaminants associated with freshwater in tributaries is dictated to a large extent by tidal mixing. Tidal currents act to disperse contaminants within the growing area by providing a well mixed water column. Since the growing area is subject to daily tidal influence, contaminants are continuously being flushed from the system on outgoing tides. Contaminant travel throughout the growing area is mostly confined to the main channels with limited lateral flow and dispersion to shoreline areas during higher tides. With each incoming tide, a volume of water much greater than that present at low tide returns to Little Harbor from the ocean, producing significant dilution of contaminants that may be present. Water returning to the growing area on an incoming tide probably still contains some contamination carried out with ebb tides, which could be significant just after low tide. Water samples were collected from four sites during two tidal cycle studies. At the mouth of the harbor (T1), FC levels were relatively low, but highest at low tide (Figure 10), decreasing to very low levels at mid ebb and low tides. The intermediate levels at mid-rising tide could reflect the return water composed of a mixture of contaminants discharged out of the harbor at low tide with contaminant-free ocean water. At Sheafes Point (T6), the channel under the Rt. 1B bridge (T13) and at the Rt. 1A bridge (T14), FC were again highest at low tide, with relatively lower levels at the other tidal stages (Figure 10). For all four sites, FC levels were always highest at low tide, confirming the typical assumption that low tide is the adverse tidal condition for water quality. No significant contaminant transport from sources other than the tributaries was apparent from the data.

V. Water Quality Studies

A. Map of sampling stations

Figure 3 shows the sites established by the NH Division of Public Health Services in order monitor the water quality of the growing area. Of the 11 sites, 5 are actually in the potential growing area and 6 are in areas that may affect water quality in the area. Several sampling sites have been added to the area since the last survey was performed in 1991. They are: T14, which was added to give a better representation of water quality in the southern portion of the Little Harbor; LH2, which reflects the water quality conditions around Wentworth Marina; and WC1 and T7, which give data for upstream portions of the two tributaries directly entering the area. Thus, 2 of the 5 sites (40%) within the growing area are new since last year. All of the additional sampling sites fill gaps in spatial coverage and provide data necessary for classifying all of the potential clam flats in the area.

B. Sampling plan justification

Systematic random sampling was used to obtain all water samples at low tide. Samples were therefore obtained under both normal and adverse conditions. Other water quality studies for other areas in coastal New Hampshire have shown differences in fecal coliform counts at high and low tide, with low tide being the adverse tidal condition.

C. Sample data analysis

The database for sampling sites in to the potential growing area (T1, T6, T13, T14, LH2) and other sites in the survey area (T5, T7, T8, T9, T10, WC1) are presented in Table 3. Included in the table are the fecal coliform concentrations/100 ml for each station and sampling date, the geometric mean FC concentrations, the number of samples collected and the 90th percentile score. The site numbers may be cross referenced with Figure 3 for exact geographic location. No site has the minimum of 30 recent samples required for data analysis for classification (NSSP, 1993). The results of the data analysis indicate that sites T1, T13, T14, and LH2 in the survey area and T5, T8 and T9 in the Back Channel area meet the requirements for approved classification using the Systematic Random Sampling Program (i.e. geometric mean < 14 FC/100 ml and the 90th percentile < 43 FC/100ml; NSSP, 1993). Site T6 at Sheafes Point in the survey area meets the criteria for geometric mean but just misses for 90th percentile. Site T7 is a freshwater site. Sites WC1 and T10 satisfy the criteria for restricted waters. If the FC value at T6 for 11/29/94 (when 1.48" of rain fell in two days) is omitted based on a rainfall condition (see below), then the calculated value for the 90th percentile would be 34.3, meeting the criteria.

VI. Interpretation of Data in Determining Area Classification

A. Meteorological and hydrographic effects on bacterial loading

The classification of the growing waters depends on the 90th percentile value calculated for water quality data. This value assumes that intermittent pollution events are unknown and random. One potentially identifiable and definable condition that may be a consistent cause of pollution is rainfall-associated runoff. Table 11 shows the number of DPHS or JEL samples collected from the proposed growing area (sites T1, T6, T13, T14, and LH2) associated with rainfall events of >0.63" of rainfall during a 48 hour time period and samples where ≤0.63 inches fell. In addition, the number of samples that had fecal coliform concentrations >43/100 ml are also noted for each condition. Overall, there were 29 DPHS and 11 JEL sample events (40 total) for which data were collected for one or more sites within the classified area. Of these sample dates, 2 occurred at times where >0.63" rain fell in 48 h, both of which had samples with FC >43/100 ml. For these 2 events there were 8 water samples analyzed at the 5 sites, 7 of which had FC >43/100 ml. These events had 1.48" (11/29/94; DPHS) and 2.76" (11/15/95; JEL) of rain in 48 h. Overall, the 8 samples collected during the other 2 events had FC ranging from 33-890/100 ml, with 6 samples having >100 FC/100 ml. Both events occurred in November when approved clam flats are typically open. During another event where 0.63" rain fell in 48 h (8/7/95; JEL), the 1 critical site (T13) sampled had 20 FC/100 ml. The data suggest that the more severe (>1"/48 h) storms can significantly impact water quality in the survey area during critical periods.

The 43 FC/100 ml value was violated on 6 of the 38 dates following periods where 0-0.63' rain fell in 48 h. There were 135 samples collected on these dates, and only 8 of these samples had FC >43/100 ml. These data suggest that pollution events are not always associated with rainfall. However, the frequency of samples having FC >43/100 ml (88% samples) is much greater during rainy (>1.4"/48 h) periods than the frequency (6% samples) during drier (0-0.63" rain/48h) periods. For both rainy events, every water sample had FC >30/100 ml, suggesting that rainy events have widespread and consistent negative impacts on water quality.

Follow-up studies should focus on a range of storm events to better define what types of rainfall events cause significant water quality impacts. In addition, studies should be conducted to define how long it takes the water quality to return to safe levels of FC following polluting events. In general, certain rainfall events appear to produce unfavorable effects on water quality that are consistent and definable in the classified area. Events that appear to significantly impact water quality are those that have >0.63 inches of rainfall within a 48 hour time period. Rainfall events with 0-0.63 " rain in 48 h do not show consistent or widespread effects in the survey area.

B. Variability in the data and causes

Fecal coliform concentrations >43/100 ml are of concern because they exceed the tolerance factor calculated to account for the inherent variation in the MPN test. This means that FC >43/100 ml should be rare (<5% of samples) in normally distributed values for water samples with a median concentration of 14 FC/100 ml. Thus, observations of higher FC values are indicative of intermittent environmental conditions that degrade water quality to an extent that results in a greater level of variance in data than what would be associated with the MPN test. As previously mentioned, there were 8 water samples collected on 6 sampling dates where FC were >43/100 ml and rainfall was <0.63"/48 h. The calculated 6% of all water samples being >43 FC/100 ml close to the theoretical 5% variability inherent in the MPN test. The following discussion examines potentially definable causes for data variability.

Only 2 of the 8 water samples >43 FC/100 ml, both collected on 8/3/95 at LH2 and T13 and analyzed by JEL, had FC >100/100 ml. Three of the six sampling dates with >43 FC/100 ml occurred during summer months, and 4 of the 5 water samples collected on these dates were either from LH2 or T13, both near the Wentworth Marina. It is suspected that some contamination could have come from the marina during the summer when boat use is high and clam flats would normally be closed. Two of the remaining 3 dates had FC of 79/100 ml at T1 on 10/19/93 and 49/100 ml at LH2 on 1/30/96. The latter sample was collected on a day following a January thaw period when the snow depth decreased from 12" to 1" in the previous 6 days. This suggests that snowmelt could have had some influence on the water quality in the area, even though FC at T6, T13 and T14 were <12/100 ml on the same date. The value of 79 FC/100 ml at T1 on 10/19/93 followed a 6-day period without rainfall. However, at T6 FC=33/100 ml and at T13 FC=23/100 ml. On both dates, FC at T8 in Sagamore Creek were the highest recorded by DPHS at 230 FC/100 ml, suggesting that some event from that area could have had some influence on water quality in Little Harbor. The remaining date was 12/7/93 when FC=46/100 ml at T6. This sampling occurred after 1.7" rainfall fell on the date 2 days prior to sampling. Other sites (T1 and T13) sampled on 12/7/93 had FC <7/100 ml. The overall low levels of FC detected during periods where <1.4" of rainfall had occurred in the previous 48 h suggests that random, undefined events that produce unsatisfactory FC levels (>43/100 ml) had only mild impacts on water quality in Little Harbor. Whereas no definable condition associated with FC >43/100 ml were apparent (other than rainfall events of >0.63"/48h), water quality conditions during snowmelt periods in January an early springtime should be investigated. Relatively significant rainfall events with >1 inch of rainfall in 48 hours are a concern. Severe impacts on water quality have been documented in Great Bay following heavy rainfall events of >4" during 48 h periods. This occurred twice during the last six years as recorded by JEL scientists: once during Hurricane Bob in 1991 when 6.06" fell in 2 days, and once in September, 1994 after 4.22" of rain fell in 48 h. Both events caused considerable contamination of the approved shellfish area in the Great Bay Estuary.

VII. Conclusions

A. Map showing classification
  to be completed by DPHS
B. Legal description
  to be completed by DPHS
C. Management plan
  to be completed by DPHS
D. Recommendations for improvement of sanitary survey

In ensuing years, we recommend that sampling near the borders of the potential growing area be expanded to include more sites at the southern boundary where there are expansive mudflats and along transects up into Witch Creek and Berry Brook to provide for more exact classification relative to upstream contamination. A more detailed survey could also be expanded into the extensive mudflat areas of Back Channel area out to the Piscataqua River. Obviously, the influence of stormwater and runoff from the CSO and other sources in Portsmouth would need to be thoroughly assessed. In addition, the eastern shoreline of the Back Channel, the Boatswain Hill area in New Castle, has relatively dense houses with septic systems built typically 20-30 years ago.

It is important to maintain a schedule that allows for frequent sampling at all routine sites. At present, the number of samples that have been analyzed for the newer sites in the survey area are inadequate, i.e., there are <30 samples. Even for all of the longer-term routine sites there are <30 samples available for classification purposes. The tolerance factor level of 43 FC/100 ml can be violated for a few samples and the 90th percentile limit can still be met if the database includes a significant proportion of low FC values. In other words, less frequent sampling may pose a greater risk for a small number of high values forcing classification of approved areas to be changed to a conditional classification. Conditional classifications require much more intensive management and a great deal of effort to accurately define the exact condition under which areas need to be closed. Thus, frequent sampling in areas typically unaffected by pollution events will most likely support the more desired approved classification.

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Table 1. Potential pollution sources impacting the growing area with relevant sample sites.

Site	Source	Water body	Impact	Relevant sample sites
PS1	Wentworth marina	Little Harbor	Direct	LH2, T13
PS2	Wentworth condominiums stormwater	Little Harbor	Direct	LH2
PS3	Little Harbor mooring field	Little Harbor	Direct	T1, LH2, T13
PS4	Wentworth golf course	Little Harbor	Direct	T6
PS5	Portsmouth WWTP	Back Channel	Indirect	T5
PS6	Portsmouth CSO	Back Channel	Indirect	T9

Table 2. **Sample sites used to determine water, shellfish and sediment quality in the Little Harbor area.**

Sample site	Agency	Location	Purpose
T1	NH DPHS	mouth of Little Harbor, N breakwater	classify survey area
T5	NH DPHS	north channel, Goat Island bridge	classify survey area
T6	NH DPHS	Little Harbor at Sheafe's Point	classify survey area
T7	NH DPHS	Berry Brook at Brackett Rd.	classify survey area
T8	NH DPHS	Sagamore Creek, Mike's Marina	classify survey area
T9	NH DPHS	Shapleigh Island bridge	classify survey area
T10	NH DPHS	Pierces Island bridge	classify survey area
T13	NH DPHS	Little Harbor bridge, US Rt. 1B	classify survey area
T14	NH DPHS	Seavey Creek bridge, US Rt. 1A	classify survey area
LH2	NH DPHS	Wentworth marina	classify survey area
WC1	NH DPHS	Witch Creek, upstream E of Foyes Rd.	classify survey area
WC2	UNH/JEL	Witch Creek, golf course bridge	tributary water
WC5	UNH/JEL	Witch Creek, downstream of bridge	tributary water
WC6	UNH/JEL	Witch Creek, mouth	tributary water
PC1	UNH/JEL	ditch on shore of Pioneer Cove, west	tributary water
PC2	UNH/JEL	ditch on shore of Pioneer Cove, south	tributary water
PC4	UNH/JEL	ditch on shore of Pioneer Cove, mouth	tributary water
PC5	UNH/JEL	Pioneer Cove, mouth	tributary water
SC1	UNH/JEL	Seavey Creek, ditch on SW shoreline	tributary water
SC2	UNH/JEL	Seavey Creek, ditch on SW shoreline	tributary water
WRL1	UNH/JEL	wetland ditch on Wild Rose Lane	tributary water
SS1	UNH/JEL	Seavey Creek clam flat, near mouth	sediment sample
SS2	UNH/JEL	Pioneer Cove mudflat, mouth	sediment sample
SS3	UNH/JEL	Witch Creek mudflat	sediment sample
SS4	UNH/JEL	Sheafe's Point mudflat	sediment sample
SS5A	UNH/JEL	Triangle clam flat, SW	sediment sample
SS5B	UNH/JEL	Triangle clam flat, near bridge	sediment sample
SS6	UNH/JEL	Wentworth flat	sediment sample
Clam flat 1/CF1	UNH/JEL	Odiorne Point State Park, SW shore	clam sample
Clam flat 2/CF2	UNH/JEL	Odiorne Point State Park, N shore	clam sample
Little Harbor/NHLH	UNH/JEL	bed near the mouth, NE shore	mussel sample
Shapleigh I/NHSI	UNH/JEL	bed near bridge, NE shore of island	mussel sample
Clark Cove/MECC	UNH/JEL	bed along SW corner of cove	mussel sample
Hampton Harbor/NHHS	UNH/JEL	bed under US Rt 1 bridge on N side	mussel sample
Brave Boat Harbor/MEBH	UNH/JEL	bed along channel near mouth, S side	mussel sample
Odiorne Point/NHOP	UNH/JEL	bed in cove at SE corner of point	mussel sample

Table 3. Fecal coliform concentrations (per 100 ml) in water samples analyzed by NHDPHS: 1/93-6/96.

Site #	T1	T5	T6	T7	T8	T9	T10	T13	T14	LH2	WC1	Durham rainfall (in/24h) in time prior to sampling 48	24	0
Date*														
3/2/93	1.8	2			2	1.8	7.8					0.01	0	0
4/6/93	31	6.8	6.8		17	6.8	49	7.8				0.06	0	0
5/4/93	2	2	7.8		4.5	2	4	13				0	0	0
6/8/93	23	1.8	33		17	13	17	21				0.47	0	0
7/6/93	2	1.8	64		17	33	33	70				0	0	0
9/14/93	1.8	7.8	4.5		11	17	49	2				0	0	0
10/19/93	79	6.8	33		230	2	17	23				0.04	0	0
12/7/93	6.8	22	46		13	22	23	4.5				1.7	0	0
1/11/94	13				49		17					0	0	0
4/5/94	1.8	1.8	4.5		1.8	2	130	7.8				0	0.23	0
6/7/94	6.8	1.8	21		48	11	7.8	1.8				0	0	0
7/19/94	1.8	2	23		33	1.8	49	4				0	0	0
8/16/94	1.8	1.8	2		2	1.8	49	6.8				0	0	0.33
9/20/94	4.5	7.8	17		26	110	33	13				0.77	0	0
10/18/94	14	2	1.8		7.8	23	13					0	0	0
11/29/94	49	70	280		79	130	3500	33				0	1.37	0.11
6/19/95	1.8	1.8	33		6.8		46	4				0	0	0
7/5/95	4.5	2	4.5		2	49	17	2				0	0	0
10/17/95				330						2	46	0.91	tr	0.01
10/31/95	1.8	7.8	13	130	23	11	4	2	7.8	2		tr	tr	tr
11/28/95	4.5	7.8	6.8	13	7.8	2	6.8	4.5	7.8	7.8	23	0	0	0.01
12/19/95	1.8	1.8	1.8	11	1.8	1.8	2	1.8	2	2	170	tr	0	0
1/30/96		79	6.8	13	230	14	23	11	11	49	17	0.09	0	0.08
2/27/96	1.8	4.5	4.5	2	11	1.8	21	1.8	4.5	6.8	58	0	0	0
3/26/96	1.8	2	4.5	9.3		13	11	2	4.5	2	2	0	0	0.01
4/29/96	1.8	2	17	17		33	95	2	7.8	7.8	790	0.03	0	0.21
5/28/96	1.8	1.8	1.8	4.5		2	4.5	1.8	1.8	1.8	180	0	0	0
6/18/96	4.5		4.5					4.5	11	4.5	4.5	0	0	0
6/25/96	2	230	1.8	33		2	49	1.8	1.8	6.8	2	0.18	0	0.1
Geometric mean	4.2	4.7	9.5	18.1	13.3	7.7	22.8	5.2	4.9	4.6	29.2			
Std. deviation	3.2	3.1	3.6	4.9	4.2	4.1	4.3	2.9	2.1	2.7	7.4			
n	27	26	26	10	23	25	27	25	10	11	10.0			
#>43/100 ml	2	2	3	2	5	3	8	1	0	1	5.0			
%>43/100 ml	7.4	7.7	11.5	20.0	21.7	12.0	29.6	4.0	0.0	9.1	50.0			
90th percentile	18.7	17.2	49.3	127.9	84.0	50.3	143.2	20.4	12.4	16.5	380.5			

* Samples analyzed for 6/19/95 through 11/28/95 were reported as "DES-LAB" values.

Table 4. **Fecal coliform concentrations (per 100 ml) in water samples analyzed by JEL: 7/95-6/96, and 24 h rainfall amounts on and before sampling dates.**

									Durham rainfall (in/24h) *in time prior to sampling date*		
Site #	T1	T6	T7	T8	T13	T14	LH2	WC1	48h	24h	0
Date											
7/20/95	1		2	20	35	0.5	51	5	0.26	tr	0
8/3/95	30		45.5	50	385	22	173	39	0	0	0.22
8/7/95			126		20				0.95	0.44	0.19
8/22/95					10	1.5	9.5		0	0	0
9/15/95	1	1	1	2	4	3.5	27	1	0.15	0	0
9/21/95	0.9	6	0.9	0.9	11	5	2	17	0	0	0
10/5/95	0.9		9	440	4	20	17	40	0.3	0.3	0.01
11/15/95	105	154	980		460	860	294	3350	0	0.08	2.68
2/27/96	1	6	4	12	1	2	5.5	130	0	0	0
5/9/96	9	12			38	20.5			0	0	0
5/28/96	0.5	2.5			1.5		3.5		0	M	tr
5/30/96	3	8	250		5.5	15.5	2.5	56	tr	0	0.33
6/10/96	0.5	4	124	3.5	3.5	18	3	34	0	tr	0.1
6/18/96	9.5	19	52		7.5	12.5	33.5	10	0	0	0
6/25/96	0.5	1	24		2	5	1.5	12	0.18	0	0.1
Geometric mean	2.4	6.3	22.2	11.9	10.9	9.2	12.4	29.2			
Standard deviation	5.6	4.4	9.7	8.2	6.2	6.1	5.6	7.8			
n	13	10	12	7	15	13	13	11			
# > 43/100 ml	1	1	6	2	2	1	2	2			
% > 43/100 ml	7.7	10.0	50.0	28.6	13.3	7.7	15.4	18.2			

Table 5. Fecal coliform concentrations (per 100 ml) in tributary sites during dry periods in June, 1996.

WITCH CREEK

	Witch Creek upstream	Witch Creek golf course bridge	Witch Creek downstream from bridge	Witch Creek mouth
Site #	WC1	WC2	WC5	WC6
Date				
6/10/96	34	2	1.8	4
6/18/96	10			
Geometric mean	29.2	2.0	1.8	4.0

PIONEER COVE

	Pioneer Cove ditch west	Pioneer Cove ditch south	Pioneer Cove ditch near mouth	Pioneer Cove mouth
Site #	PC1	PC2	PC4	PC5
Date				
6/10/96	2	2		
6/18/96	6	0.5	2	4
Geometric mean	3.5	1.0	2.0	4.0

BERRY BROOK/SEAVEY CREEK

	Berry Brook	Seavey Creek ditch west	Seavey Creek ditch west downstream
Site #	T7	SC1	SC2
Date			
6/10/96	124		
6/18/96	52	2	2
Geometric mean	22.2	2.0	2.0

WILD ROSE LANE WETLAND

	Wild Rose Lane wetland
Site #	WRL1
Date	
6/10/96	
6/18/96	6
Geometric mean	6

Table 6. Dissolved nitrate, ammonium and ortho-phosphate concentrations (μM) at Little Harbor sites along the shoreline of the Wentworth-by-the-Sea golf course: May-June, 1996.

Site	Nitrate	Ammonium	Phosphate
5/16/96			
T6	5.87	1.82	0.41
WC6	3.62	6.56	0.32
PC5	3.19	2.93	0.49
6/10/96			
T6	2		

Table 7. **Tissue concentrations for metal (ppm; µg/g DW) and organic (ppb; ng/g DW) contaminants in blue mussels from areas in and around Little Harbor: 1991-94.**

Metal (ppm)	FDA guideline*	1991-92 Little Harbor Rye/New Castle NH	1991-92 Shapleigh I. Portsmouth NH	1992 Odiorne Point Rye NH	1993 Hampton Harbor Hampton Beach NH	1991-94 Ave. Clark Cove/Seavey I. Kittery ME	1993 Ave. Brave Boat Harbor Kittery ME
Ag		0.5	0.1		0.1	0.2	0.4
Al		340	370		94	190	135
Cd	25	2.1	1.8		2.1	2.0	2.6
Cr	87	6.6	7.8		1.6	3.7	3.7
Cu		46	55		6.4	8.3	7.0
Fe		440	630		270	640	680
Hg	1	0.5	0.5		0.5	0.4	0.2
Ni	533	3.6	3.0		1.4	2.2	2.9
Pb	11.5	4.7	4.6		2.4	6.2	2.3
Zn		240	150		120	110	99
% solids		10.4	12.0		16.5	14.3	12.5
Organic compound (ppb)							
PCBs	13,000	32	51	32	9.6	66	3.2
PAHs		170	380	130	71	330	170
Cl'd Pesticides	~2,000	15.1	17.9	8.8	4.2	11.8	ND

* Established action limits in fish and shellfish (USFDA, 1990; 1993).

TABLE 8. Water Column Stratification in the Study Area

FLOOD TIDE 5/9/96

Station	Depth Range Measured (m)	Temperature Range	Salinity Range	Temp Differential Bottom to surface	Salinity Differential Bottom to surface
Harbor Mouth	3.5 - 6.0	5.5-8.1	22.8-26.8	2.6°C	4 ppt
Center of Mooring Field	3.0 - 5.5	5.5-7.8	23.1-26.1	2.3°C	3 ppt
Marina Fuel Dock	3.0 - 5.5	5.8-8.8	23.9-26.9	3°C	3 ppt
Rte 1B Bridge	3.0 -5.5	5.5-8.0	25.1-26.8	2.5°C	1.7 ppt
Sheafes Point	0.5 - 3.0	5.5-8.0	24-27	2.5°C	3 ppt
Pioneer Road Bridge	1.0 - 3.0	9.3-10.0	21.9-22.2	0.7°C	0.3 ppt

EBB TIDE 5/16/96

Station	Depth Range Measured (m)	Temperature Range	Salinity Range	Max Temp Differential Bottom to surface	MaxSalinity Differential Bottom to surface
Harbor Mouth	3.5 - 6.0	8.9-11	24.2-26	2.1°C	1.8 ppt
Center of Mooring Field	3.0 - 5.5	7.5-8	24-25	0.5°C	1 ppt
Marina Fuel Dock	3.0 - 5.5	8.0-9	23.8-24.8	1 °C	1 ppt
Rte 1B Bridge	3.0 -5.5	8-8.8	24-24.8	0.8 °C	0.8 ppt
Sheafes Point	0.5 - 3.0	10.8-11	21-25	0.2 °C	0.2 ppt
Pioneer Road Bridge	1.0 - 3.0	11.2-12	15.9-24.2	0.8 °C	0.2 ppt

Table 9. TIDAL CIRCULATION IN THE STUDY AREA

FLOOD TIDE CIRCULATION

Station	Direction (magnetic)	Velocity Range cm/sec	Avg. Velocity cm/sec
Harbor Mouth (1)	160°	8 to 40	27
Center of Mooring Field (2)	80°	7 to 32	20
Marina Fuel Dock (3)	90°	6 to 40	25
Rte 1A Bridge (4)	165°	13-115	75
Sheafes Point (5)	50°	2 to 25	19
Pioneer Road Bridge (6)	330°	7 to 30	20

EBB TIDE CIRCULATION

Station	Direction (magnetic)	Velocity Range cm/sec	Avg. Velocity cm/sec
Harbor Mouth (1)	342°	7 to 45	30
Center of Mooring Field (2)	270°	3 to 32	23
Marina Fuel Dock (3)	280°	6 to 55	30
Rte 1A Bridge (4)	340°	7 to 120	80
Sheafes Point (5)	205°	5 to 27	25
Pioneer Road Bridge (7)	140°	7 to 37	28

Table 10. **Bacterial indicator concentrations (per 100 g DW sediment or shellfish) in surface sediments and in shellfish from sites in the Little Harbor area: 1995-96.**

SEDIMENTS

Site	Seavey flat	Pioneer flat	Witch Creek	Sheafes Point	Triangle flat SW	Triangle flat near bridge	Wentworth flat
Site #	SS1	SS2	SS3	SS4	SS5A	SS5B	SS6
C. perfringens	110000	30000	133000	222000	318000	270000	1990
Fecal coliforms	22	71	67	71	120	220	3
E. coli	22	35	67	71	120	220	3

SHELLFISH (Fecal coliforms/100 ml)

Site	Seavey flat	Odiorne east flat	Witch Creek flat	Odiorne west flat	Rt. 1B bridge north	Triangle flat near bridge	Wentworth flat	Berry Brook
Site #	6/SS1	2	3/SS3	1	T13	4/SS5B	5/SS6	T7
Date								
8/7/95					3000			240
8/21/95		300	110	900				
8/23/95						2200	80	
9/15/95							130	
10/3/95	130							
Geometric mear	130	300	110	900	3000	2200	102	240

* All analyses are for clam (Mya arenaria) tissue except 8/7/95 T7 (C. virginica) and T13 (Mytilus edulis)

Table 11. Effect of rainfall events (>0.63"/48 h) on fecal coliform levels in DPHS and JEL samples collected from the approved growing area.

SAMPLE DATES

DPHS

	Total	Rainfall > 0.63"	Rainfall 0-< 0.63"
# of sample dates	29	1	28
# >43/100 ml	5	1	4
# < 43/100 ml	24	0	24

JEL

	Total	Rainfall > 0.63"	Rainfall 0-< 0.63"
# of sample dates	11	1	10
# >43/100 ml	3	1	2
# < 43/100 ml	8	1	8

Combined

	Total	Rainfall > 0.63"	Rainfall 0-< 0.63"
# of sample dates	40	2	38
# >43/100 ml	8	2	6
# < 43/100 ml	32	0	32

WATER SAMPLES

DPHS

	Total	Rainfall > 0.63"	Rainfall 0-< 0.63"
# of water samples	99	3	96
# >43/100 ml	7	2	5
# < 43/100 ml	92	1	91

JEL

	Total	Rainfall > 0.63"	Rainfall 0-< 0.63"
# of water samples	44	5	39
# >43/100 ml	8	5	3
# < 43/100 ml	36	0	36

Combined

	Total	Rainfall > 0.63"	Rainfall 0-< 0.63"
# of water samples	143	8	135
# >43/100 ml	15	7	8
# < 43/100 ml	128	1	127

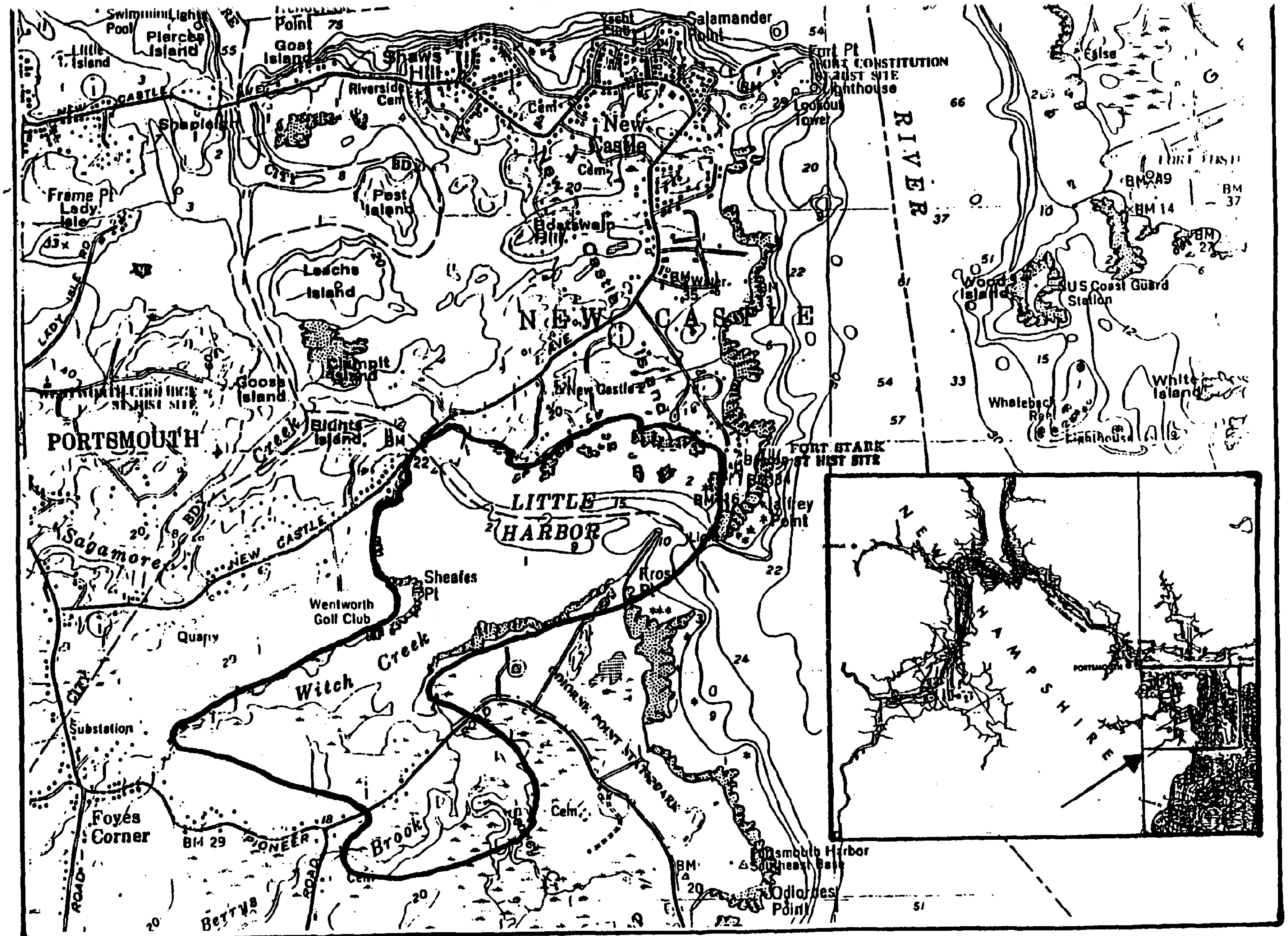


Figure 1. Map of the Little Harbor, Witch Creek and Seavey Creek survey area. Inset shows location in coastal New Hampshire.

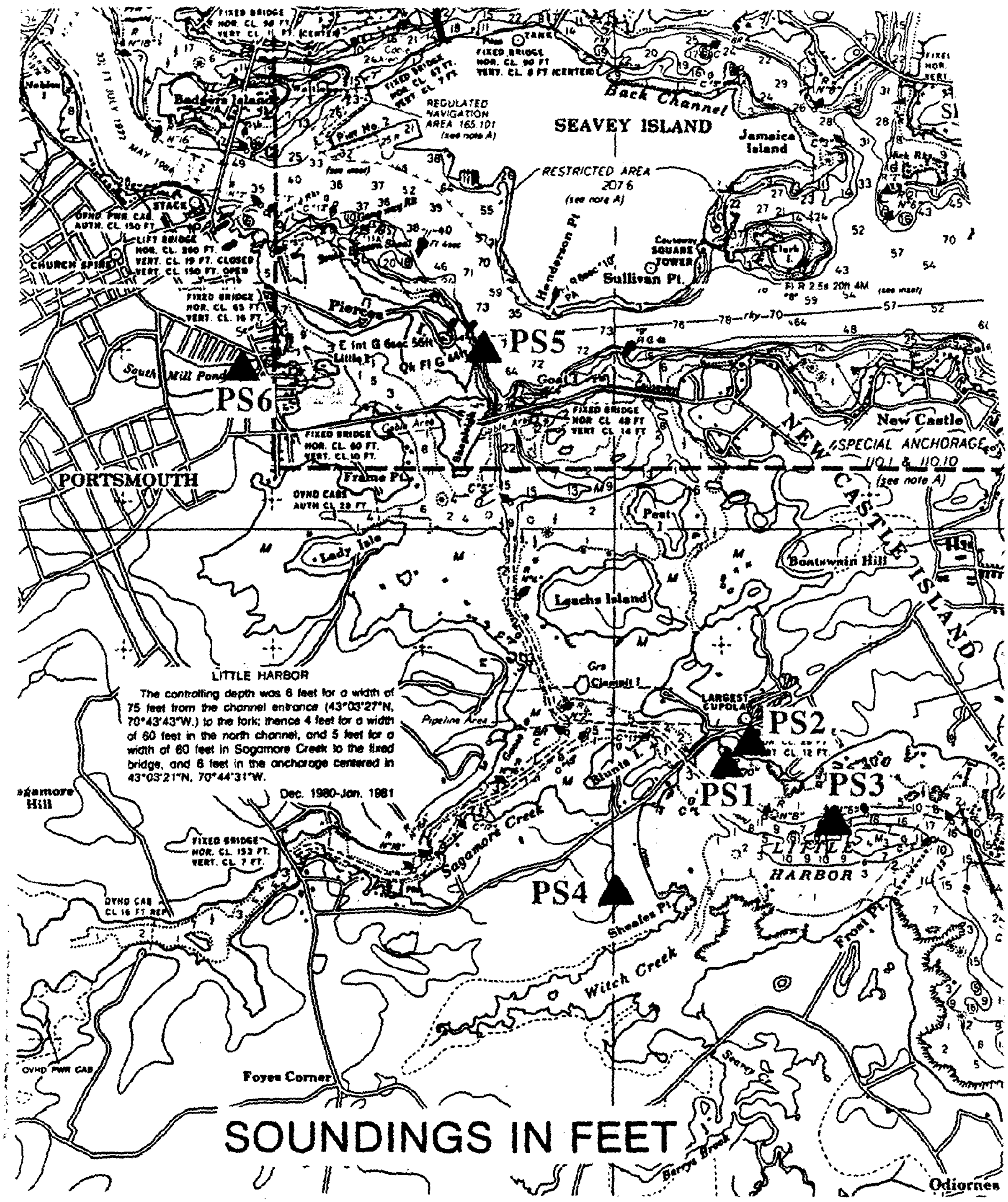


Figure 2. Potential pollution sources in and around the survey area.

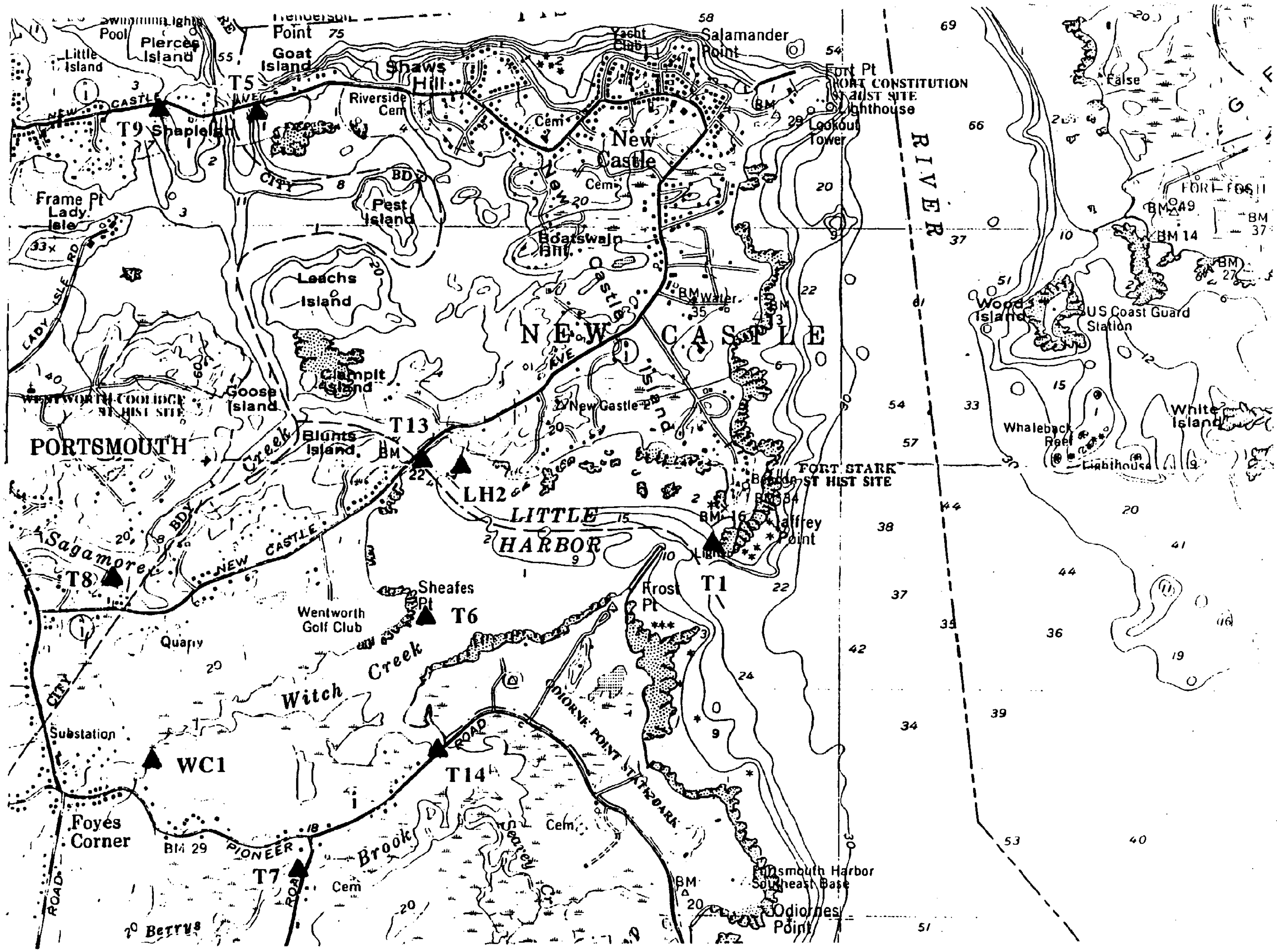
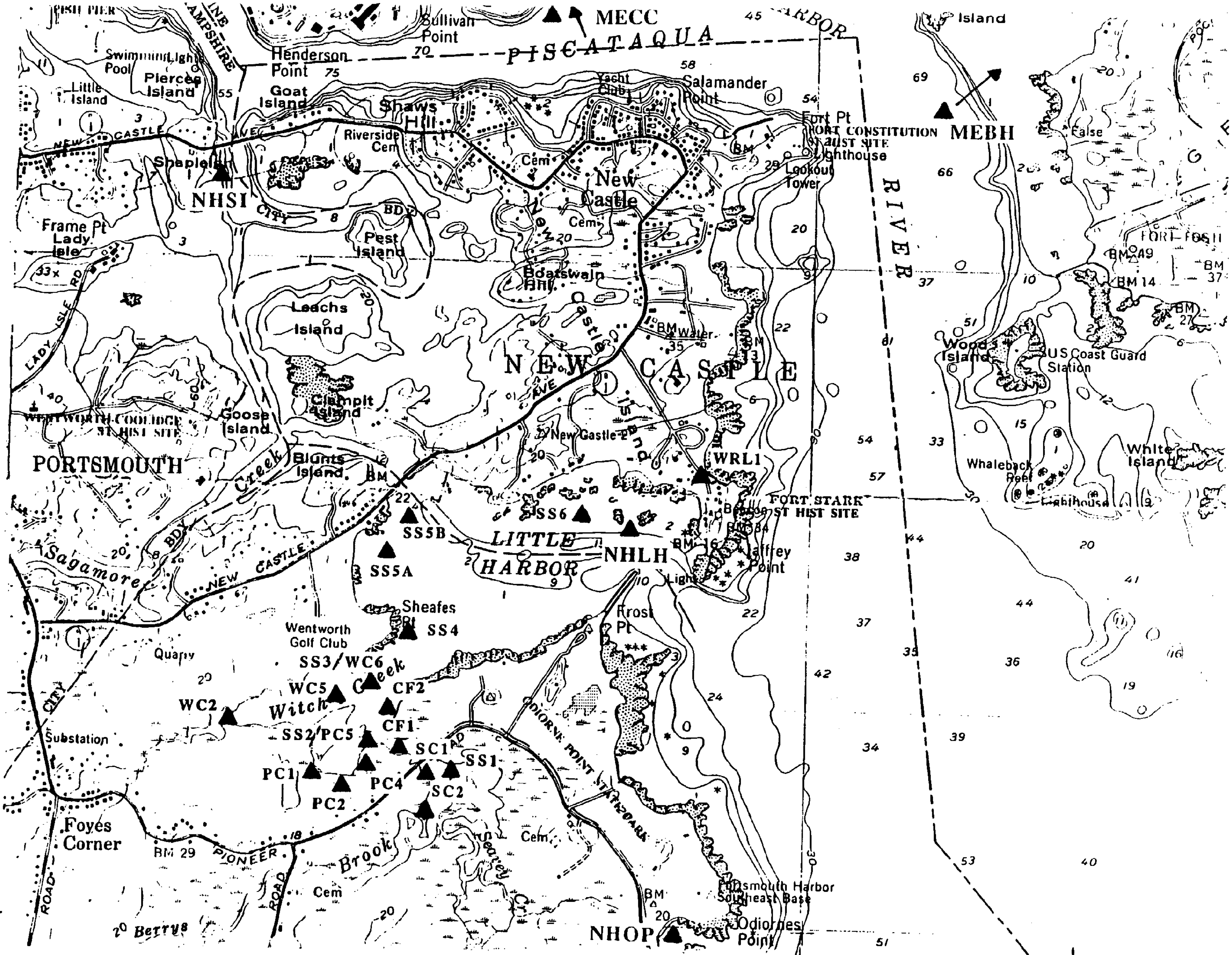


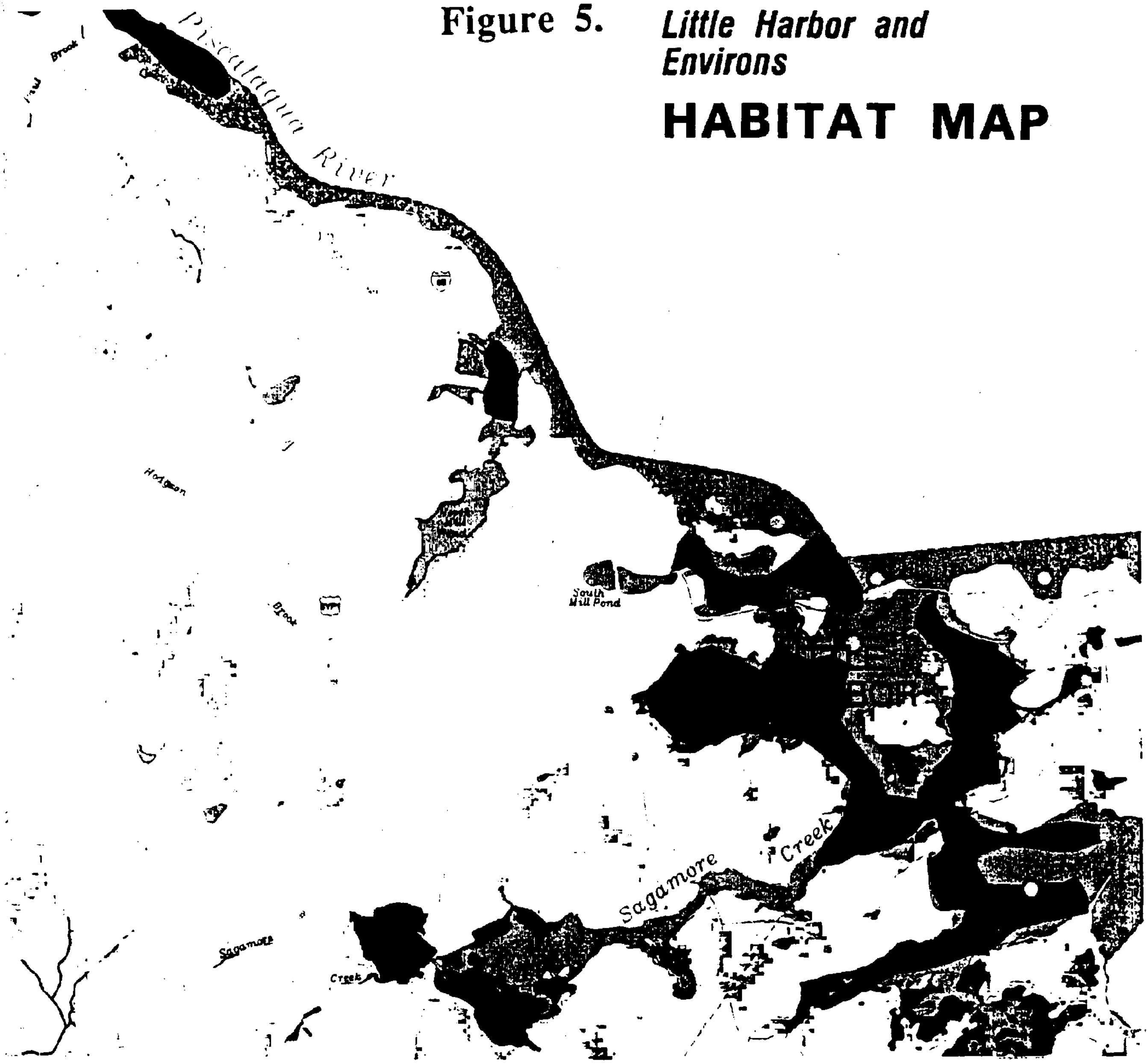
Figure 3. NH DPHS routine sampling sites in the survey area.



MECC
MEBH
NHSI
NHLH
NHOP
WRL1
SS6
SS5B
SS5A
SS4
SS3/WC6
WC5
WC2
CF2
CF1
SS2/PC5
SC1
SS1
PC1
PC2
PC4
SC2
PISCATAQUA
RIVER
HARBOR
NEW CASTLE
New Castle Island
LITTLE HARBOR
PORTSMOUTH
Sullivan Point
Henderson Point
Goat Island
Shaws Hill
Riverside Cem
Salamander Point
Yacht Club
Fort Pt
FORT CONSTITUTION ST HIST SITE
Lighthouse
Lookout Tower
New Castle
Boatswain Hill
Pest Island
Leachs Island
Clampit Island
Goose Island
Blunts Island
WENTWORTH-COOLIDGE ST HIST SITE
Swimming Pool
Pierces Island
Little Island
Shapleigh
Frame Pt
Lady Isle
Sagamore Creek
Sheafes Pt
Wentworth Golf Club
Witch Creek
Quarry
Substation
Foyes Corner
Brook
Seavey Cr
Berrys
ODIORNE POINT STATE PARK
Frost Pt
Jaffrey Point
FORT STARK ST HIST SITE
Portsmouth Harbor Southeast Base
Odiornes Point
Wood Island
US Coast Guard Station
Whaleback Reef
White Island
Lighthouse
False
Island
NEW HAMPSHIRE
NEW CASTLE AVE
CITY BDY
PIONEER ROAD

Figure 5. *Little Harbor and Environs*

HABITAT MAP



Map by:

Complex Systems Research Center
Institute for the Study of Earth,
Oceans and Space
University of New Hampshire

March, 1996

p Scale: 1 inch to 3500 ft.

HAMPSHIRE

LEGEND

- Bald eagle wintering sites
- Soft-shell clam beds
- Oyster beds
- Osprey nesting sites
- Freshwater wetlands
- Salt marsh
- Productive heron nesting sites
- Eelgrass beds

DATA SOURCES

[illegible]

Locus Map:

Piscataqua Watershe
and Coastal Draina

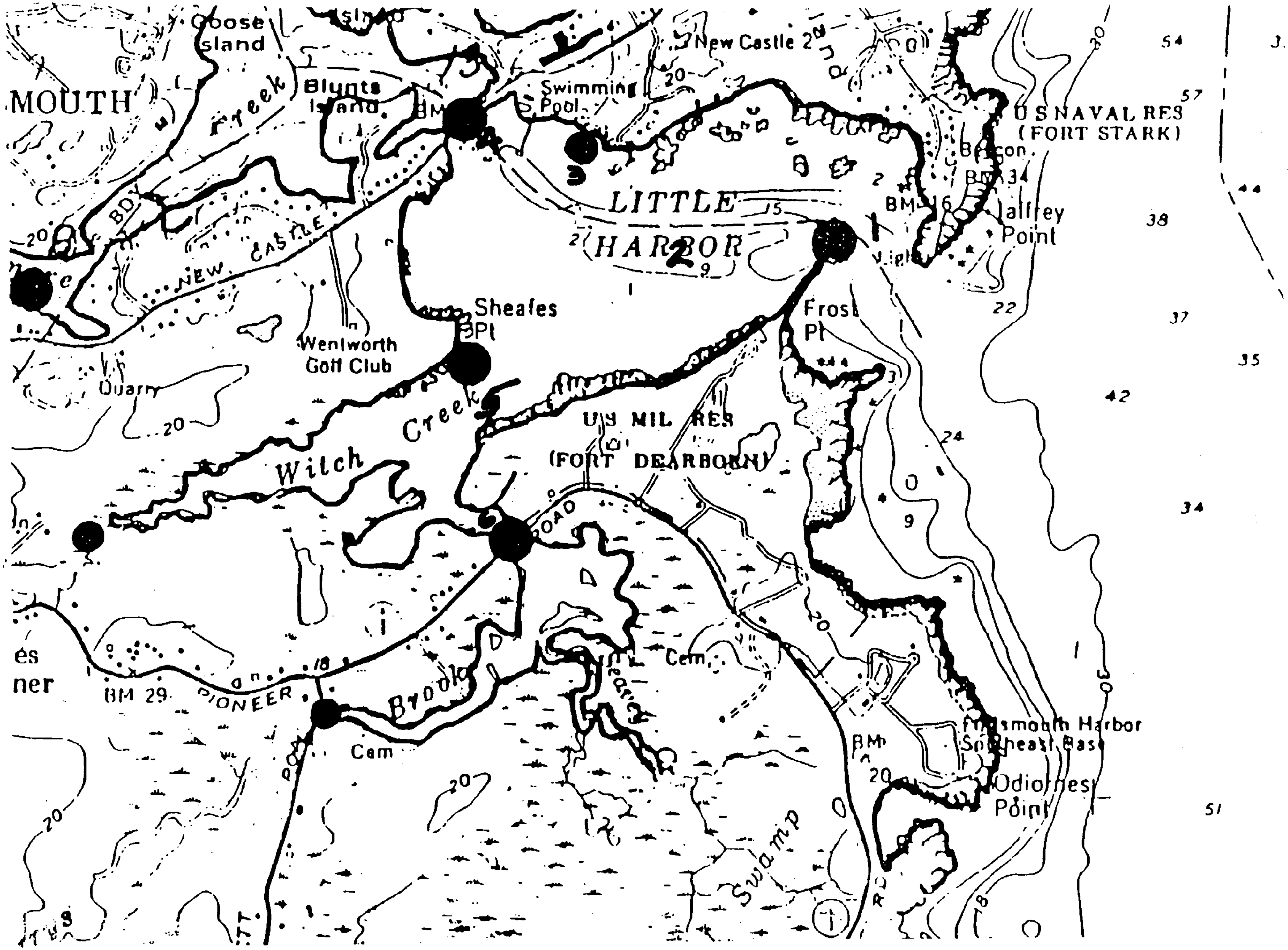


Figure 6. Map of the study area showing the locations of current velocity and direction measurements and vertical

Figure 7. Fecal-borne bacteria in sediments from different sites in Little Harbor: Spring, 1996.

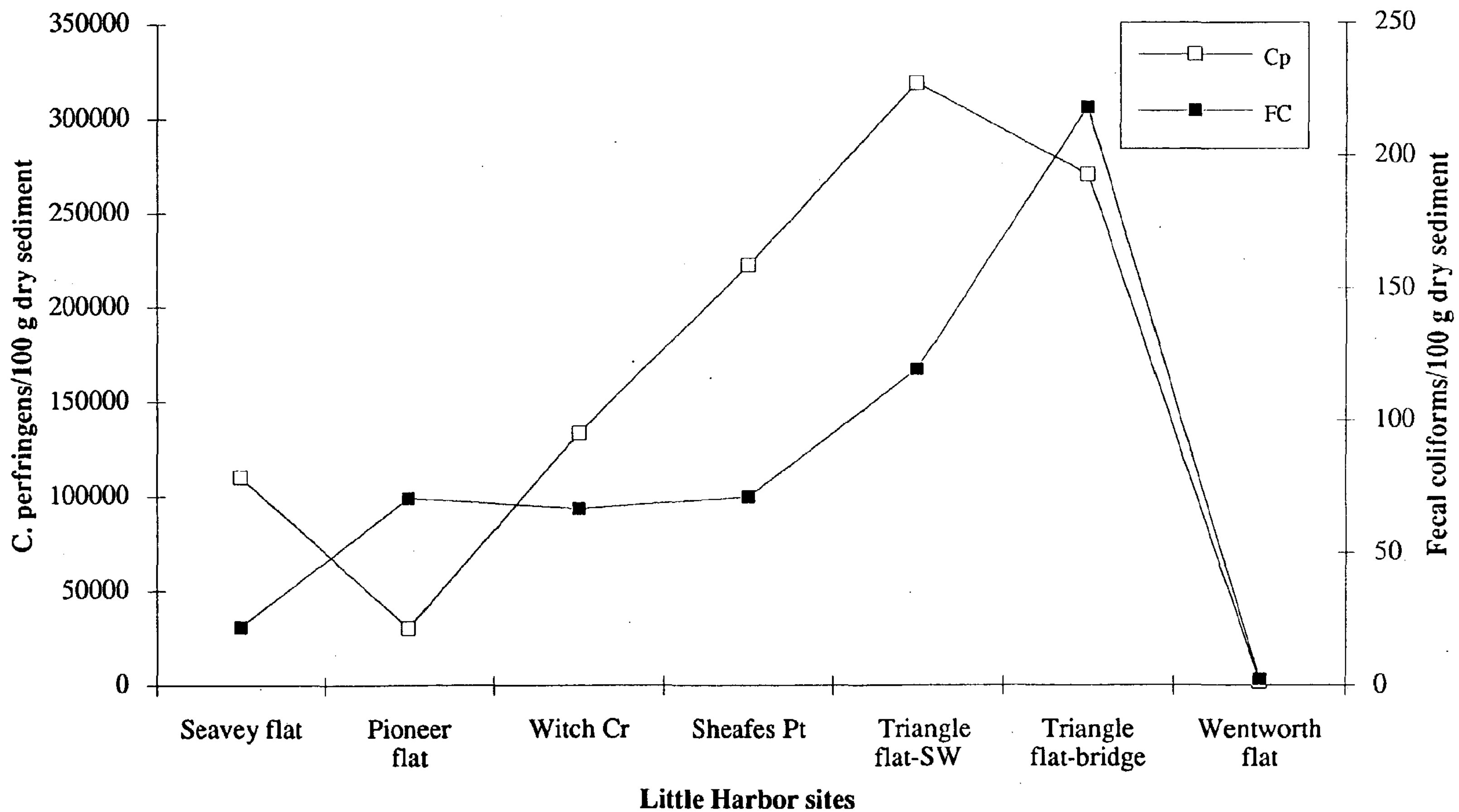


Figure 8. Fecal coliforms in clams and sediments from different sites in Little Harbor: 1995-96.

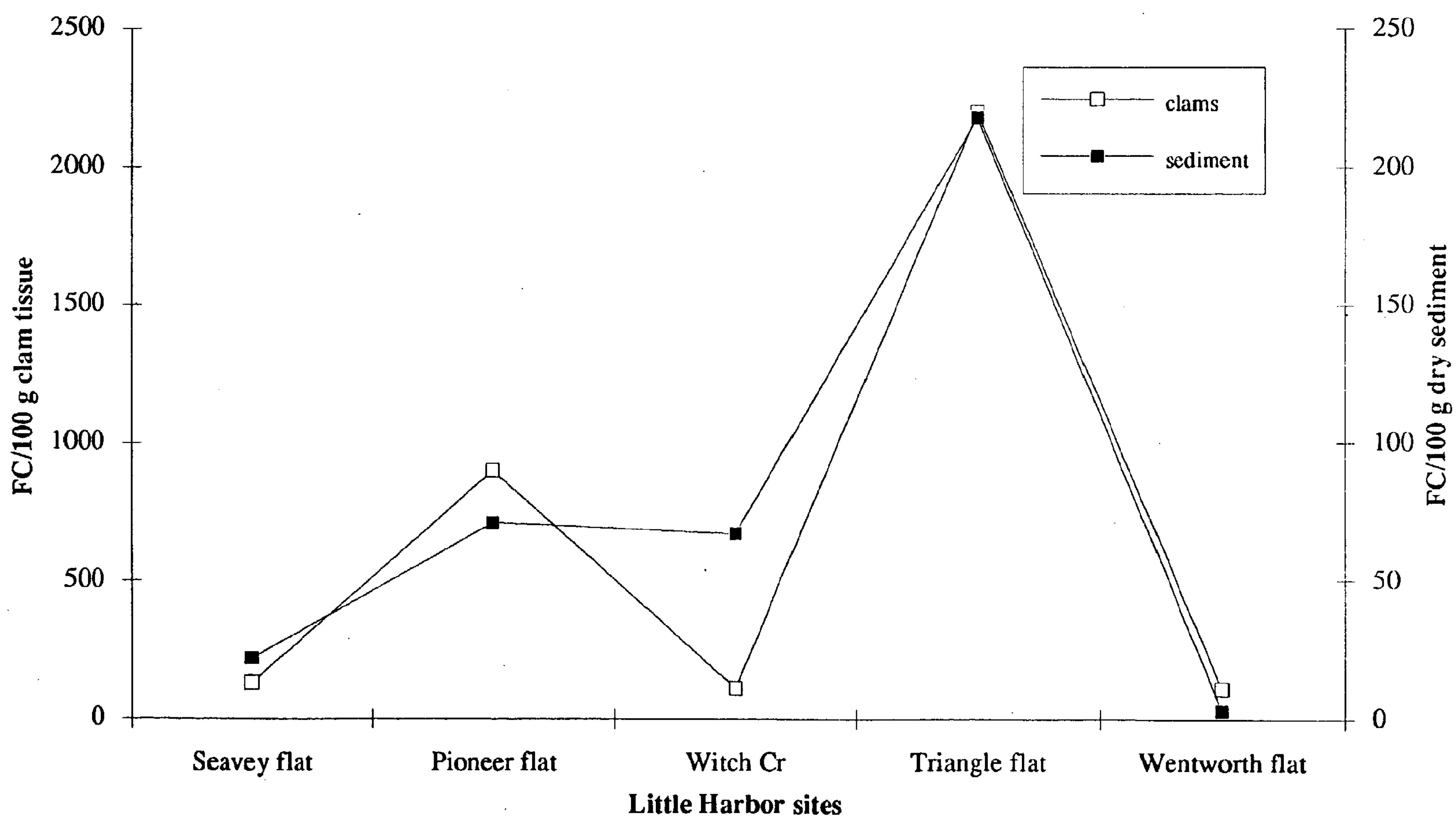
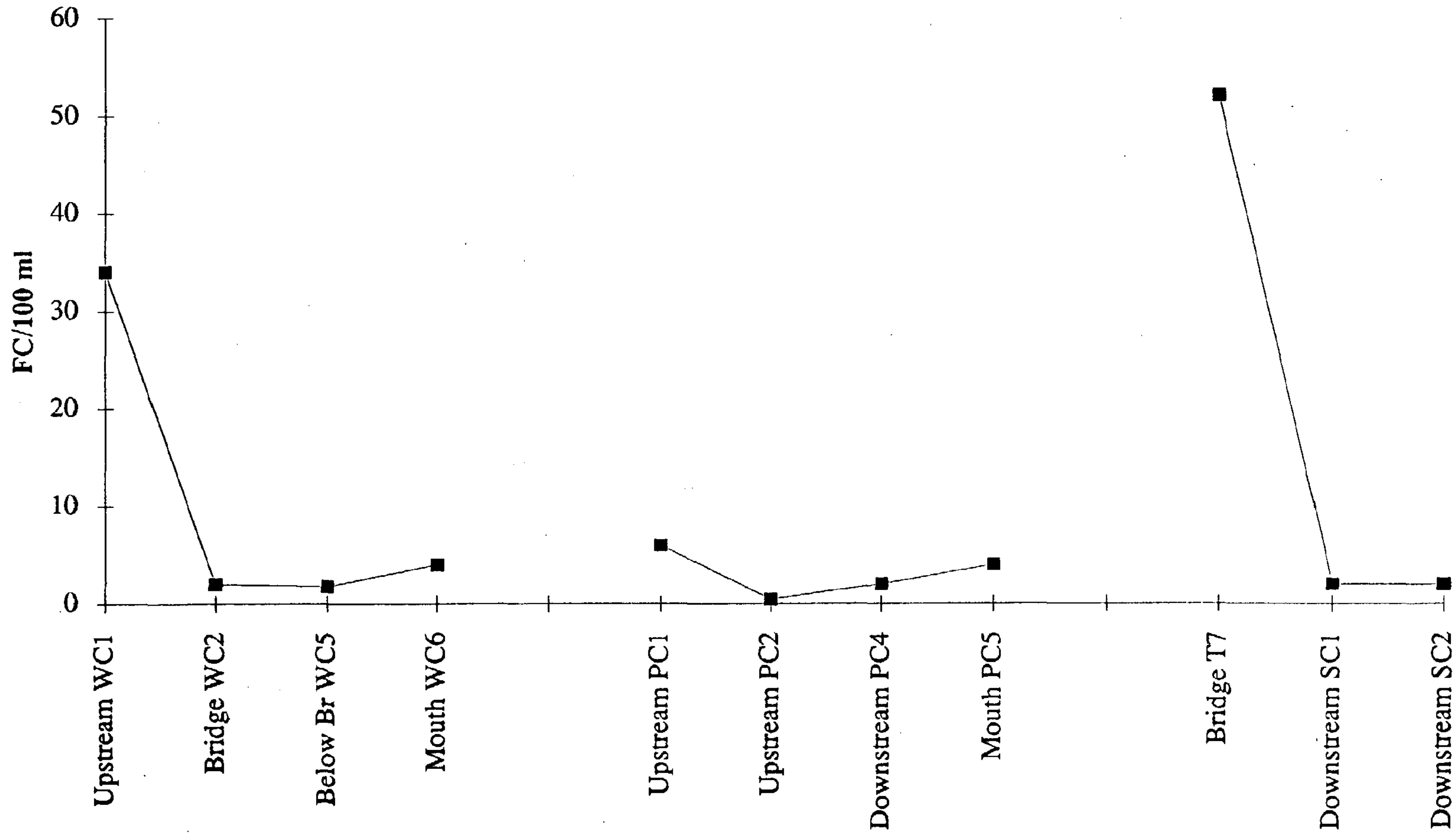


Figure 9. Fecal coliforms at sites along transects of tributaries (WC-Witch Ck; PC-Pioneer Cove; SC-Seavey Cr) to Little Harbor during dry periods in June, 1996.



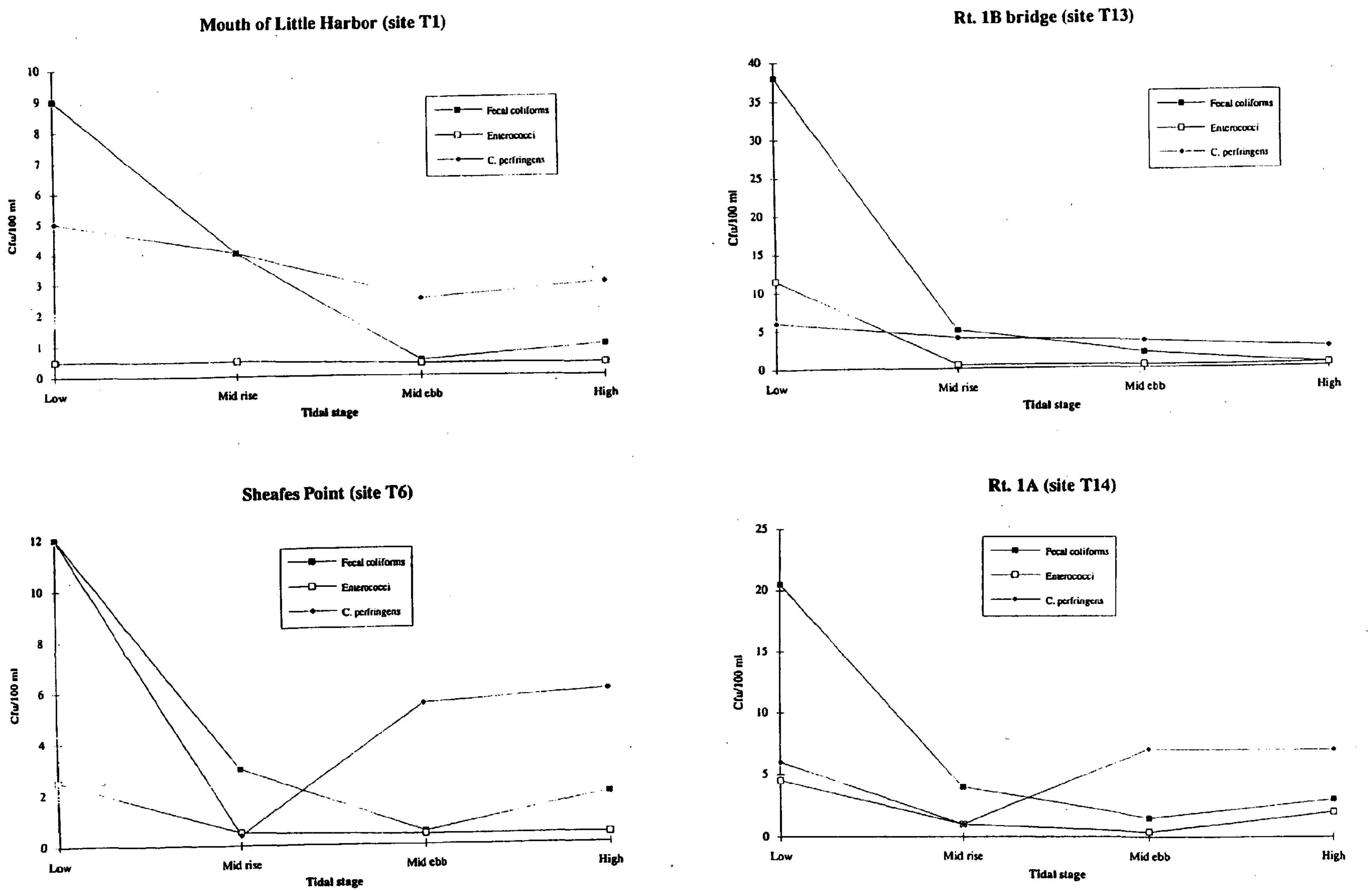


Figure 10. Fecal coliform concentrations (per 100 ml) at sites during different tidal stages: Spring, 1996.

APPENDIX A

Assessment of the Clam (*Mya arenaria*) population in the study area

Seven potential clamflats were identified in the study area. Locations of the flats are shown in Figure A1. Five of the seven flats were surveyed in the summer and fall of 1995, and the two remaining flats were surveyed in the spring of 1996. Spatfall from the 1995 spawning season was measured on the three largest flats in the spring of 1996.

Area

Estimates of the areal extent of five of the seven clamflats were made from existing maps and field drawings. These figures are presented in Table A1. Flats range in area from 0.4 acres at flat # 1 to 12.1 acres at flat #5. The areas presented in the table correspond to suitable clam habitat only, and not the total intertidal area. Based on our field observations, suitable clam habitat consists primarily of sandy substrate, as the softer, muddy intertidal areas yielded very few clams. Total area for the five flats surveyed was estimated to be 35 acres.

Density

Clam density was determined using a series of randomly placed radial transect lines. The location of each transect was chosen from a series of grids for each clamflat using a random numbers table. A center stake with a 10 m line attached (bearing a mark at each meter) was placed in the center of a grid and a 1/2 m diameter circle bearing eight equidistant numbers was drawn around the center point. Placement of the quadrat was determined by obtaining two random numbers from the table, the first corresponding to the numbered position on the circle, the second to the metered distance from the center point. A 1/8 m2 quadrat was then placed at the center of the randomly chosen mark. All sediment underlying the quadrat was excavated to a depth of 30 cm using a clam fork and all clams were removed by hand, counted and measured. Five quadrats were run for each transect. The total number of quadrats examined was: 10 for clamflat #1; 85 for clamflat # 2; 30 for clamflat 4; 75 for clamflat #5; and 90 for clamflat #6 ; and 50 for clamflat #7. Clam densities range from a low of 1.6 clams /m2 on clamflat #1 to 12.5 /m2 on clamflat #4, with a mean density of 5.1 clams/m2 (Table A1). Clamflat #3 had very an extremely low density of clams (Table A1). The intertidal substrate in the flat was extremely soft, and was determined to be an unsuitable substrate for Mya.

Abundance

The estimate abundance of clams in the study area was calculated from density and areal estimates and appears in Table A1. Total abundance was estimated at approximately 600,000 clams or roughly 530 bushels of harvestable clams.

Length frequency distributions

Length frequency distributions of the clams at four of the seven flats are shown in Figures A2 through A6. Though there are some differences from flat to flat, most clams were > than 30 mm, with the greatest number of clams in the flats in the 40-70 mm size range. According to established shell growth curves, most clams in these flats are > 3 years old, indicating poor recruitment or survival of larvae and/or spat in the 1993 and 1994 seasons.

1995 Spatfall

Spatfall for the 1995 spawning season was measured on the three largest clamflats in the study area in the spring of 1996. Though spatfall assessment in the spring would tend to underestimate actual settlement and metamorphosis, it more accurately predicts overwintering survival. Spat were sampled using a 10 cm coring tube. Samples were taken at four equidistant points in the intertidal zone, extending along a line perpendicular to the water line from the upper intertidal to the low tide line. These perpendicular lines were spaced 10m apart. At each sampling point two 8 cm cores were obtained and sieved on site through a 1 mm sieve. All clams were removed, counted and measured. Of the three flats surveyed, the greatest density of *Mya arenaria* spat was found at the Seavey Creek flat, where density was 106 clams/m2. The mean size of the clams was 4.55 mm and ranged from 2.2-8.9 mm. Spat density at the Wentworth flat was 53/m2, while the mean size was 6.05 mm and size range 2.65-12.8. Spat density at the Odiorne flat was low, with only 18 spat/m2. The mean size was 5.55 mm and ranged from 3.3-7.9 mm.

Spat density at the four intertidal levels was compared using ANOVA. Though fewer spat were found in the upper intertidal cores, no significant differences were indicated by ANOVA at any of the flats.

Spat density in the study area is relatively low compared to productive clamflats where > 1000/m2 are often found. This may be due to the low density of adults throughout the area, in addition to high predation pressure from worms and crabs.

Table A 1. Clam Density and Abundance in the Study Area

Clamflat #	Location	Acres	Density #/m2	Total Area m2	Abundance	# Bushels 1200 clams/bu
1	Odiorne-West	0.4	1.6	1,618	2,589	2
2	Odiorne-East	8.6	4.4	34,796	153,102	128
3	Witch Creek	Unsuitable substrate				
4	Triangle	3.2	12.53	12,950	162,264	135
5	Wentworth	12.1	2.02	48,968	98,915	82
6	Seavey	6.4	5.07	25,900	131,313	109
7	Berrys Brook	4.2	4.65	18,817	87,499	73
Total		34.9	5.0	143,049	635,682	530

TABLE A 2. 1995 Spatfall in the study area

Clamflat #	Location	# Cores	#spat	#/m2	Mean size (mm)	Size range (mm)
2	Odiorne East	120	17	19	5.33	3.3-7.9
5	Wentworth	120	49	53	6.05	2.6-12.8
6	Seavey Creek	68	56	106	4.55	2.2-8.9

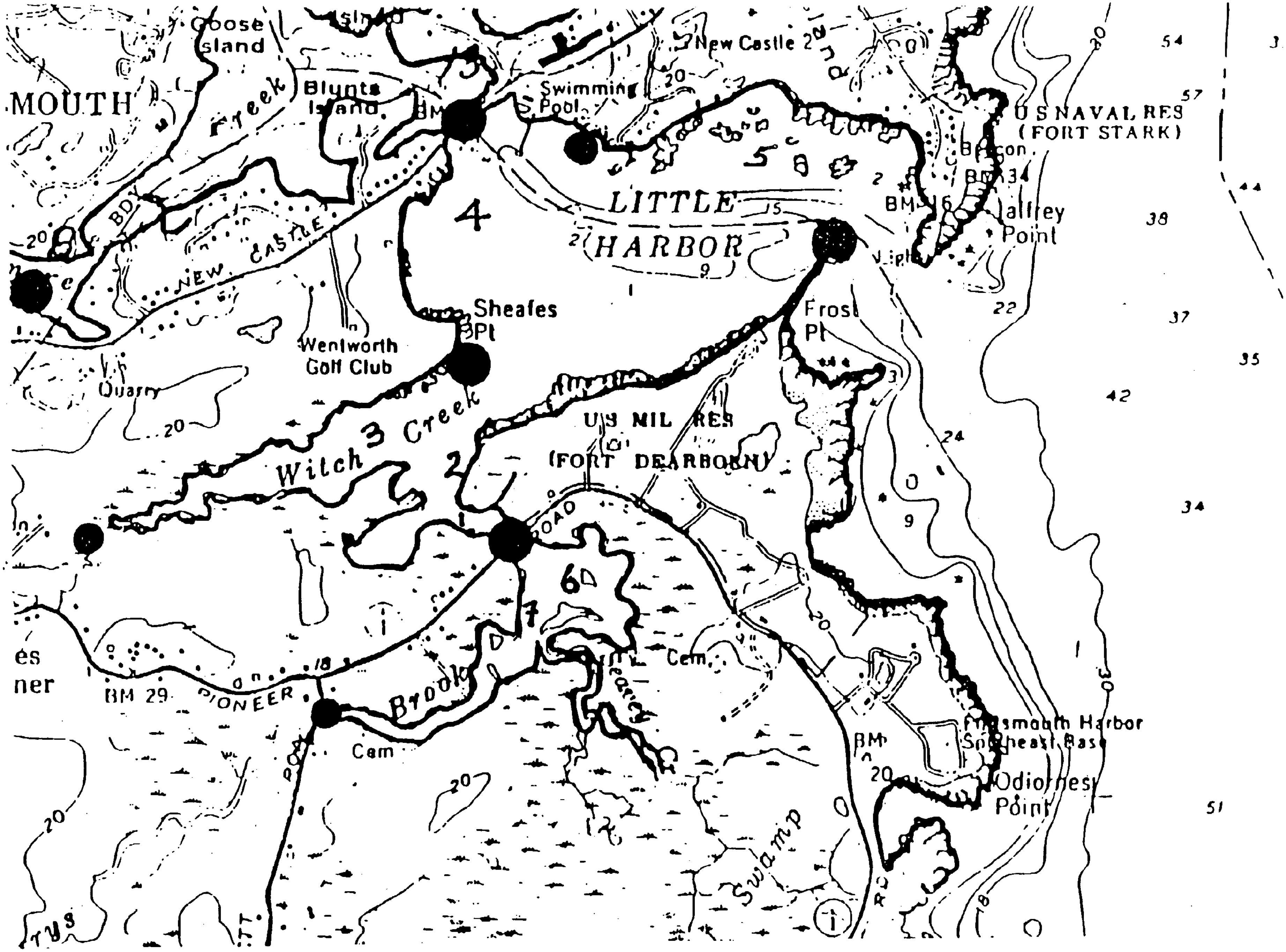

Goose Island
Blunts Island
Freek
MOUTH
NEW CASTLE
New Castle
Swimming Pool
U S NAVAL RES (FORT STARK)
LITTLE HARBOR
Jaffrey Point
Sheafes Pt
Wentworth Golf Club
Quarry
Witch Creek
Frost Pt
US MIL RES (FORT DEARBORN)
ROAD
PIONEER
BM 29
Brook
Cem
Swamp
Odiornes Point
1
2
3
4
5
6
7

Figure A 2. Size Frequency Distribution of clams at clamflat #2

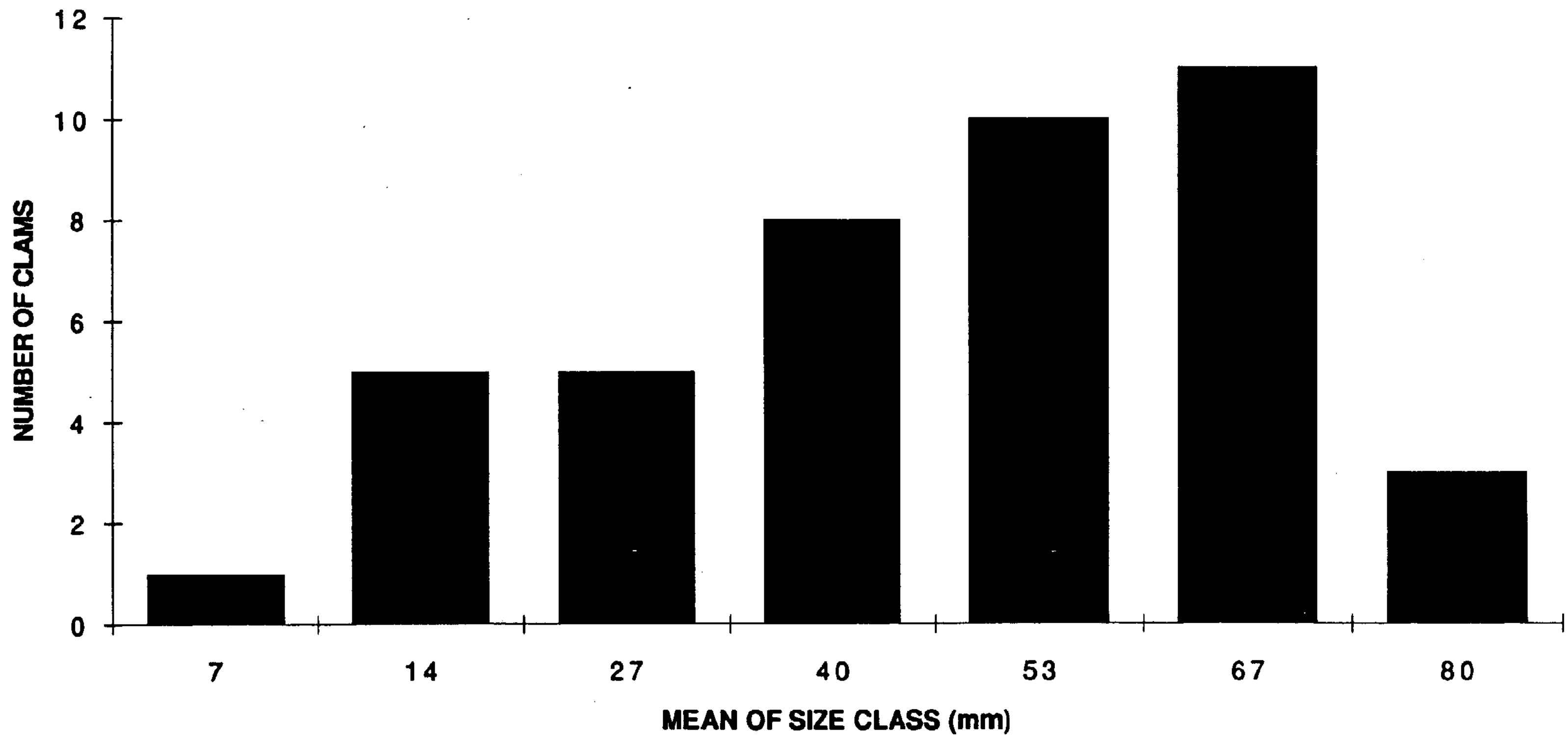


Figure A 3. Size frequency distribution of clams at clamflat #4

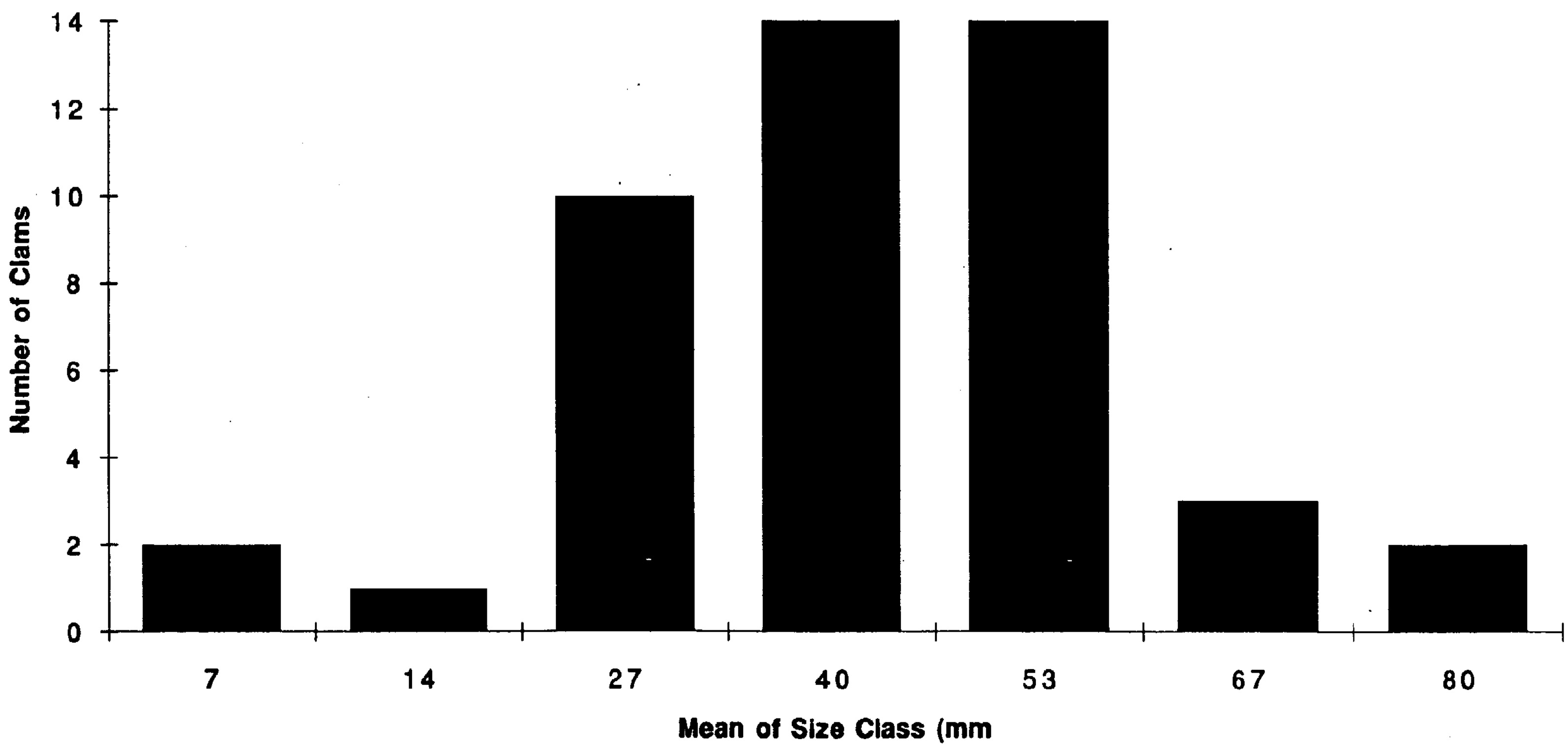


Figure A 4. Size frequency distribution of clams at clamflat #5

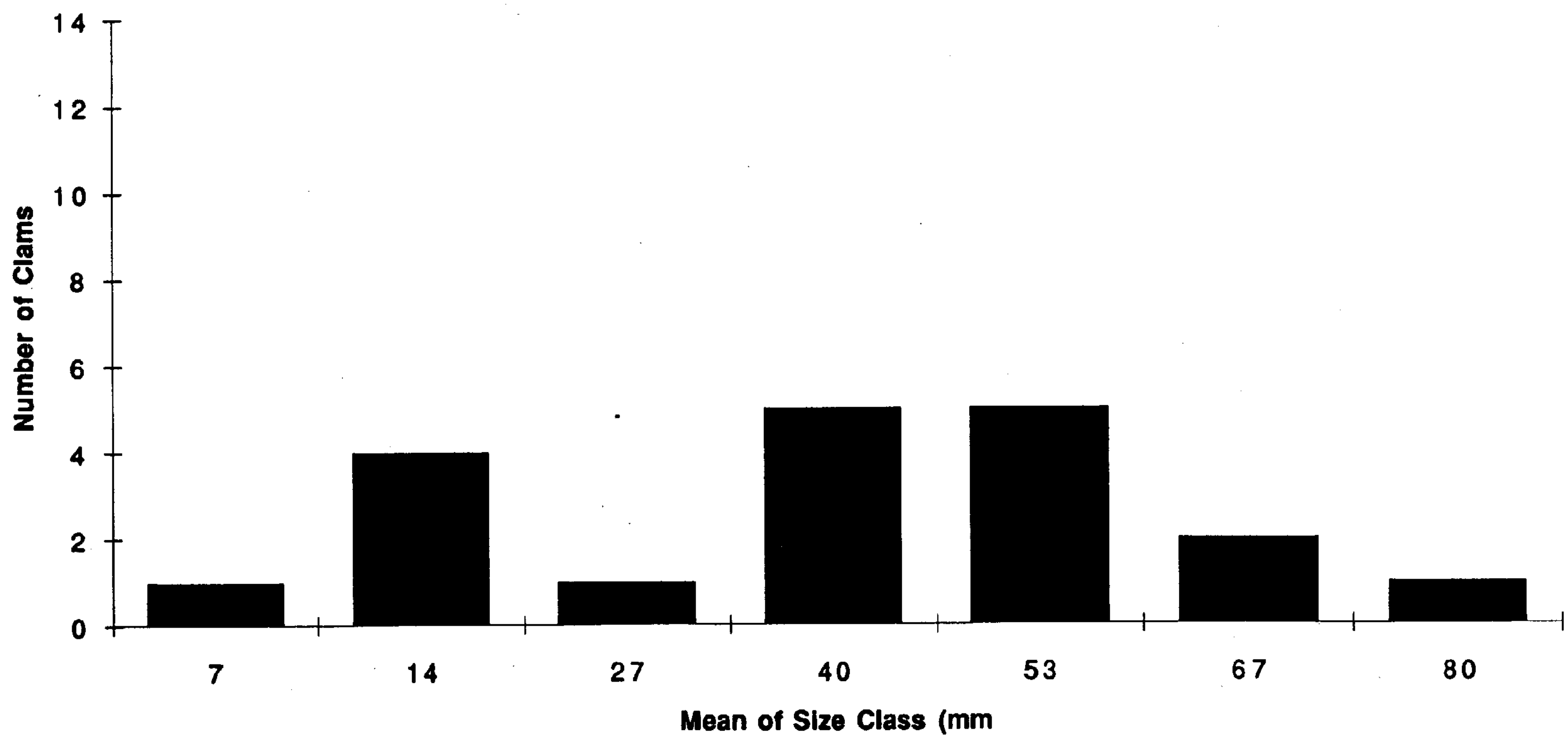


Figure A 5. Size frequency distribution of clams at clamflat # 6

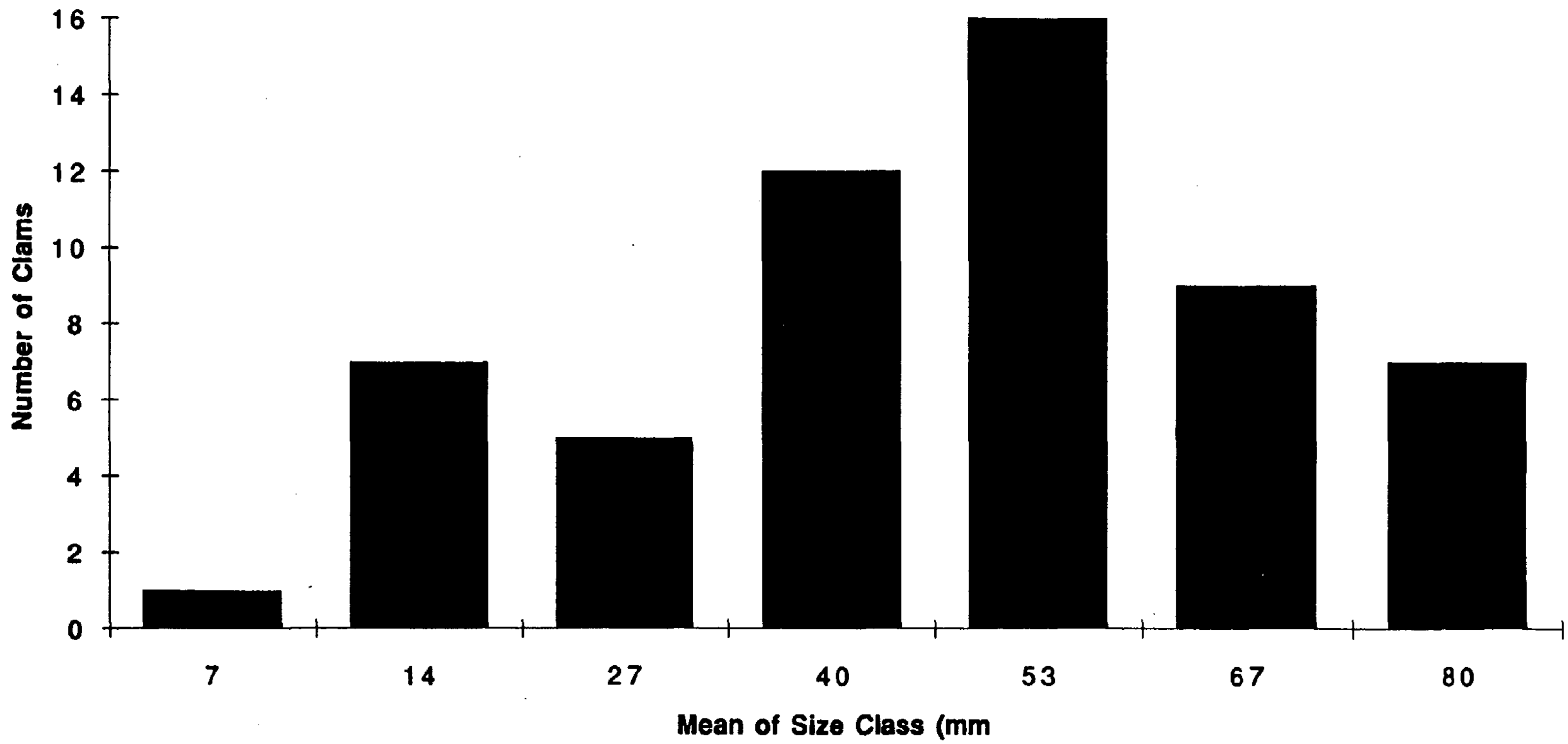
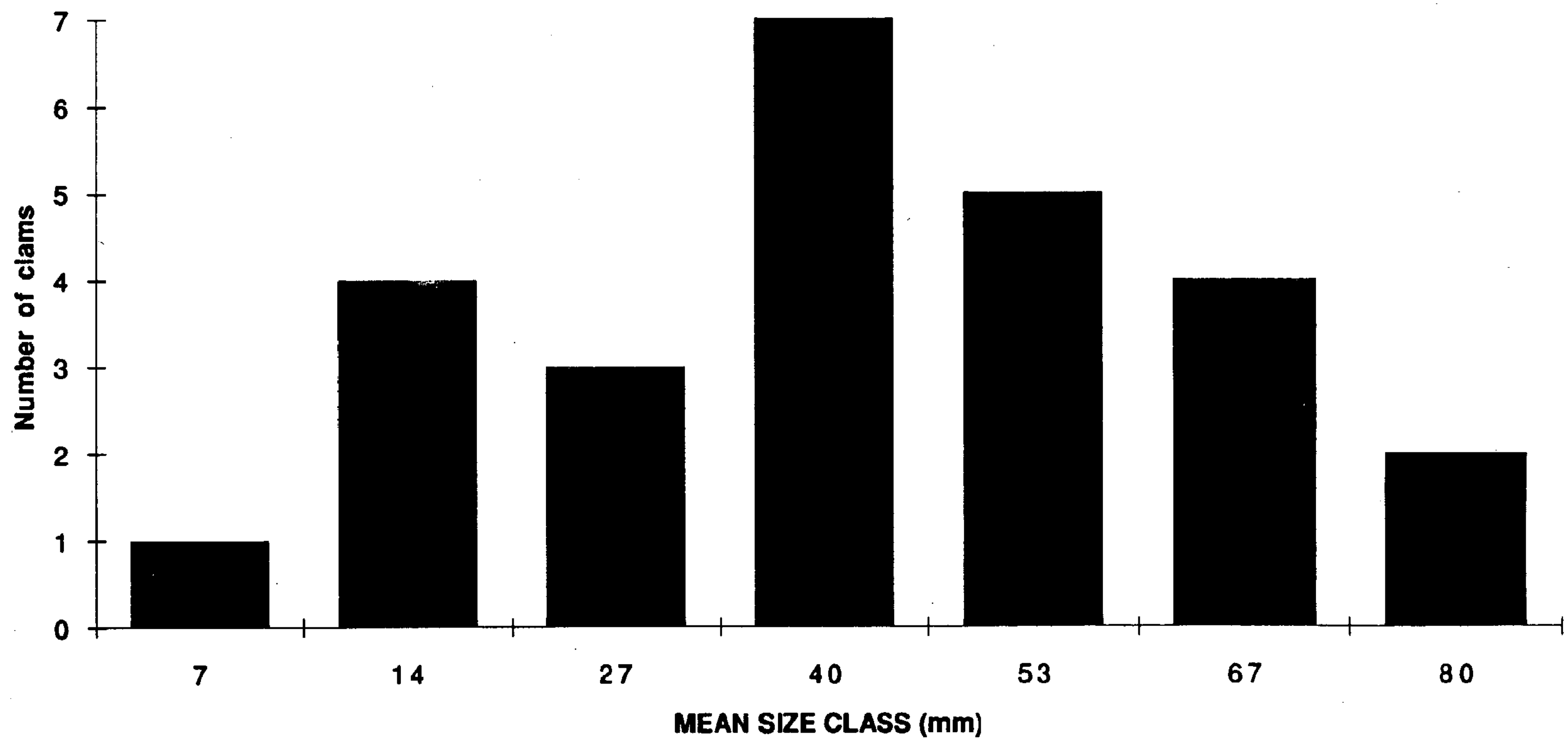


Figure A 6. Size frequency distribution of clams at clamflat # 7



Appendix B. Properties and septic systems in towns surrounding the survey area.

MAP-LOT#	NAME	MAILING ADDRESS	PROPERTY ADDRESS	SEPTIC INFO	OTHER INFO
RYE					
22-57	Nona Philbrook	300 Central Rd. Rye 03870	? Brackett Rd. Rye 03870		vacant lot
22-58	Pamela S. Desjardins	181 Brackett	181 Brackett	new septic in 1990	
22-59	Dr. Ernest C. Desjardins	171 Brackett	171 Brackett		subdivision approved 1971
22-60	Dante L. Tosi	165 Brackett	165 Brackett		subdivision approved 1980
22-61	Marion S. Rand	218 Wallis Rd. Rye	? Brackett		large vacant lot
22-62	Robert J. Leary	135 Brackett	135 Brackett		subdivision approval 1981
22-63	Richard Spaulding	121 Brackett	121 Brackett	septic approved 1993	
22-64	Murray L. & Diane C. Mason	115 Brackett	115 Brackett	new septic 1988, replaced 1990	
22-65	Bordman G. Randall	99 Brackett	99 Brackett		
22-66	John F. Fort III	2003 Milford St. Houston TX	115 Brackett	new septic 1988, replaced 1990	cross listed with 22-64
22-67	Lee H. Roper	85 Brackett	85 Brackett		new house 1977
22-68	Elizabeth M. Wendall	6 Brackett	39 Brackett	septic approved 1993	39 acres bordering Seavey's Creek
22-68-1	Jeffery H. Marple	PO Box 4130 Portsmouth	51 Brackett		subdivision Approved 1980
22-68-2	Kevin Barton	35 Brackett	35 Brackett	septic approved 1992	borders Seavey's Creek
22-70	Anne Reagan	Costa Mesa CA	? Brackett		vacant lot
22-71	Elizabeth C. Hoffman	17 Brackett	17 Brackett		
22-72	David E. Junkins	3 Brackett	3 Brackett		
22-73	David E. Junkins	3 Brackett	179 Pioneer St		borders Seavey's Creek
22-74	Town of Rye	10 Central Rd	? Pioneer St		58.7 acres bordering Seavey's Creek
22-75	James A. McLaughlin	57 Park Terrace East, NY,NY	115 Pioneer		
22-76	James A. Robertson Jr.	85 Pioneer	85 Pioneer		
22-77	Town of Rye	10 Central Rd	? Pioneer		21.3 acres of vacant lot
22-78					
22-79					
22-80					
22-81	Great Island Trust Co.	PO Box 245 Rye	? Pioneer		part of WBTS
22-82	Florence L. Ouellette	182 Poineer	182 Pioneer		
22-83	Stuart R. Kahl	200 Pioneer	200 Pioneer		new house in 1989
22-84	Micael J. Simchik	260 Pioneer	235 Pioneer		vacant lot bordering Berry's Brook
22-85	Wendell G. Cummings	40 Brackett	215 Pioneer		vacant lot
22-86	Charles P. Wendell	6 Brackett	6 Brackett		
22-87	Donna M. Theoboldi	20 Brackett	20 Brackett		building permit issueed 1990
22-88	Midred E. Welsh	30 Brackett	30 Brackett		subdiv. apr. 1978, purchased 1990
22-89	Micael F. Thiel	34 Brackett	34 Brackett	new septic passed inspection 1993	large lot bordering Berry's Brook
22-90	Wendall G. Cummings	40 Brackett	40 Brackett	septic installed 1979 w/ leach field	
22-91	Dana F. Kent	PO Box 95 Rye	50 Brackett	new septic 1993	

22-92	Frederick P. Jeter	60 Brackett	60 Brackett	septic built & approved 1989	
22-93	Forrest L. Beasley	16 Shoals View Dr. Rye	100 Brackett		
22-94	George Darragh Jr.	Little Silver NJ	110 Brackett		
22-95A	Dolores F. Lintz	120 Brackett	120 Brackett	septic approved 1991	
22-95B	James von Prief Fardelmann	380 Grant Ave Portsmouth	150 Brackett	septic approved 1991	new house built 1991
22-96	Robert W. Scherer	140 Brackett	140 Brackett	septic approved 1993	cross listed w/ 22-100
22-98	Town of Rye	10 Central Rd	? Brackett		2 vacant lots
22-99	Marion S. Rand	218 Wallis Rd Rye	? Brackett		vacant lot
22-100	Gary W. Wendell	189 Lincoln Ave Portsmouth	140 Brackett	septic approved 1993	
22-101	Conservation Commision	PO Box 429 Rye	? Brackett		vacant lot
22-102	Domenico Scognamiglio	1210 Ocean Blvd Rye	170 Brackett	new septic approved in 1992	Malfunctioning septic in 1979
22-103	Maria S. Manougan	180 Brackett	180 Brackett		new house 1986
22-104	Wesley C. Pike Jr.	88 Temple St Nashua	190 Brackett	new septic 1993	
23-4	Town Conservation Comission		Wallis Sands State Park		
23-11	Town Conservation Comission		3.10 acres		vacant lot
23-12	Town Conservation Comission		2.48 acres		vacant lot
23-13	Town Conservation Comission		2.83 acres		vacant lot
23-14	Town Conservation Comission		10.05 acres		vacant lot bordering Seavey's Creek
23-15	Town Conservation Comission		65.45 acres		vacant lot bordering Seavey's Creek
24-1	William S. Dugan	97 Morning St. Portsmouth	31 Pioneer		Bathroom renovations 1991
24-2	Robert M. Brown	23 Pioneer	21 Pioneer	new septic installed & approved "94	
24-3	Henry J. Cavaretta	73 Sagamore Rd.	5, 11 Pioneer		Foye's Corner restaurant, store, etc
24-28	Bruce D. Graves	191 Wentworth	191 Wentworth		property crosses street
24-29	Frances Kost	27 Baycliff Rd. Portsmouth	? Wentworth		
24-30	Split Rock Cove Trust	507 State St. Portsmouth	135 Wentworth		
24-31	Brian K. Berry	141 Wentworth	141 Wentworth		
24-32	Alfred M. McKenna	139 Wentworth	139 Wentworth		
24-33	Elsa G. Sonnabend	30 Kadaya Rd Waben MA	129 Wentwirth	new septic 1986	
24-34	Ruth B. FOrd	125 Wentworth	125 Wentworth	leach field installed 1969	
24-35	Great Island Trust Co	PO Box 245 Rye			
24-36	Paul R. Peterson	357 Richards Ave Ports.	117 Wentworth		
24-37	Great ISland Trust Co.	PO Box 245 Rye			
24-38	Paul S. Mackey	113 Wentworth	113 Wentworth		
24-39	Great Island Trust Co.	PO Box 245			WBTS
24-40	Great Island Trust Co.	PO Box 245			WBTS
24-41	Russel W. Badger	79 Harbor View Dr.	79 Harbor View Dr.		
24-42	Carol S. Cole	77 Harbor View	77 Harbor View		
24-43	Anita L. Holt	71 Harbor View	71 Harbor View	new septic 1967	
24-44	Francis & Helen Davis	65 Harbor View	65 Harbor View	new septic 1982	
24-45	John E. Seybolt	75 State St. Boston MA	59 Harbor View		
24-46	Chritine B. Rasmussen	53 Harbor View	53 Harbor View		

24-47	Philip J. Voss	47 Harbor View	47 Harbor View		
24-48	Richard E. Winslow Jr.	1 Harbor View	1 Harbor View		
24-49	Anna Grace Holloway	2 Harbor View	2 Harbor View		
24-50					
24-51	Vinay D. Gandevia	Annaheim CA	12 Harbor View	new septic 1978	
24-52	Samuel Francis	PO Box 407 Rye	24 Harbor View	new septic 1979	
24-53	Edward Rowland	160 Federal St Boston MA	34 Harbor View		
24-54	Janice Sandberg	40 Harbor View	40 Harbor view		
24-55	Barbara C, Graper	46 Harbor View	46 Harbor View	new septic 1968	
24-56	Robert & Margaaret Allard	74 Harbor View	74 Harbor View	new septic 1968	
24-57	Robert E. McLaughlin	80 Harbor View	80 Harbor View	new septic 1969	
24-58	Harold C. Thomas	93 Wentworth	93 Wentworth		
24-59	Barbara Y Woodman	85 Wentworth	85 Wentworth		was issued permit to "replace pond"
24-60	Paul J. Holloway	PO Box 3400 Exeter	71 Wentworth	new house built 1991	
24-61	Great Island Trust Co.	PO Box 245 Rye	? Wentworth		WBTS- 47.77 acres
24-62	Great Island Trust Co.	PO Box 245 Rye	? Wentworth		WBTS- 5.87 acres
24-63	Great Island Trust Co.	PO Box 245 Rye	? Wentworth		WBTS- 2.13 acres
24-64	Helen G. Lawrence	106 Wentworth	106 Wentworth		
24-65	Great Island Trust Co.	PO Box 245	? Wentworth		WBTS-20.85 acres
24-66	June E. Bragdon	PO Box 129 Newcastle	150 Wentworth		
24-67	Barbara Steppo	150 Wentworth	150 Wentworth		
24-68	Edmund J. Mulcahy	812 Douglas St Manchester	? Wentworth		vacant lot
24-69	Bruce R. Graves	191 Wentworth	191 Wentworth		property crosses street
24-70	Mihael Kutchey	187 Wentworth	187 Wentworth		
24-71	Town Conservation Comission		? Sagamore Rd		vacant lot- 7.83 acres
24-72	Barbara Scammon	PO Box 584 Rye	4 Sagamore Rd	septic approved 1978	
24-73	Helen F. Scammon	PO Box 42 Portsmouth	8 Sagamore Rd		
24-74	Arden McLean	14 Sagamore Rd	14 Sagamore Rd		line adjustment approved 1991
24-75	Carol M. Fisher	PO Box 126 Rye	22 Oral Ln		
24-76	Wilfred J. Losier	2 Foyes Rd	2 Foyes Rd		
24-77	Albert C. Stewart	1 Frontier St	1 Frontier St		
24-78	James A. Derochemont	5 Frontier	5 Frontier		
24-79	Cheryl T. McGonagle	PO Box 185 Rye	9 Frontier		
24-80	Leo T. Fitzgerald	15 Frontier	15 Frontier	new septic 1978	
24-81	Great Island Trust Co.				WBTS- 8.92 acres
24-82	Michael J. Cavaretta	30 La Mer Dr Rye	? Frontier		
24-83	Francis J. Drenzek	PO Box 171 Rye	16 Frontier		
24-84	Ernest E. Sieg	PO Box 325 Rye	8 Frontier		
24-85	Timothy A. Welch Jr.	PO Box 586 Rye	4 Frontier	new septic 1981	
24-86	James J. Cavaretta	1137 Abady Ct. FL	12 Old Ferry Landing		
24-87	Barbara S. Thompson	3 Foyes Rd	3 Foyes Rd		

24-88	Norman E. Lord	14 Martin Rd Kittery ME	5 Sagamore Rd		
24-89	Douglas N. Sparks	26 Sagamore Rd	26 Sagamore		
24-90					
24-91	Glenn G. Trefethen	355 Wallis Rd	? Pioneer Rd		vacant lot
24-92	Daisey A. Heath	14 Pioneer Rd	14 Pioneer		
24-93	Paul M. Attaya	20 Pioneer	20 Pioneer		
24-94	Paul M. Attaya	20 Pioneer	22 Pioneer		realty company office
24-95	Linda & Gary Ringhoffer	28 Pioneer	28 Pioneer		
24-96	James J. Cavaretta	1137 Abady Ct Fl	? Foyes Rd		dredged Withces Creek in 1991
24-97	Michael J. Cavaretta	30 La Mer Dr Rye	? Old Ferry Landing		
24-98	Great Island Trust Co.		? Pioneer St		WBTS- 32.09 acres
24-99	Great Island Trust Co.		? Pioneer St		WBTS- 8.35 acres
24-100	Edward H. Marcotte	PO Box 497 Rye	44 Pioneer		
24-101	John J. Herbert	PO Box 95 Rye	54 Pioneer		
24-102	Great Island Trust Co.	PO Box 245 Rye	? Pioneer St		WBTS-8.35 acres
24-103	Great Island Trust Co.	PO Box 245 Rye	? Pioneer St		WBTS- 1.58 acres
24-104	Great Island Trust Co.	PO Box 245 Rye	? Pioneer St		WBTS- 1.36 acres
24-105	Shirley A. Bergeron	120 Pioneer	120 Pioneer		
24-106	Great Island Trust Co.	PO Box 245 Rye	? Poineer		WBTS- 13.20 acres
24-107	Great Island Trust Co.	PO Box 245 Rye	? Poineer		WBTS- 7.00 acres
24-108	Susan E. ELsea	220 Pioneer	220 Pioneer		subdivided 1990, borders Witch Cr.
24-109	Richard Carely	240 Pioneer	240 Pioneer	new septic 1992	borders Witch Cr. & Seavy's Creek
24-110					
24-111	Clifford A. Priest	300 Pioneer	300 Pioneer		borders Seavey's Creek
24-112	Marion Woodbridge	304 Pioneer	304 Pioneer		borders Seavey's Creek
24-113	R. Carroll Carpenter	306 Pioneer	306 Pioneer		borders Seavey's Creek
24-114	Pamela Anthony	320 Pioneer	320 Pioneer		borders Seavey's Creek
24-115	John J. Ploski	291 Pioneer	291 Pioneer	septic approved 1977	no other buildings permitted
24-116	Arthur M. Abbott	281 Pioneer	281 Pioneer		
24-117	Arthur G. Pierce	RR 2 Rte 202 Barrington	265 Pioneer	4 houses on property	borders Berry's Brook
24-118	John E. Gloor	200 Parson's Rd Rye	? Pioneer	bad septic as of 1994	
25-1	State of NH		? Ocean Blvd		land across street from Odiorne
25-2	State of NH		? Ocean Blvd		land across street from Odiorne
25-3	State of NH		? Ocean Blvd		land across street from Odiorne
25-4	State of NH		? Ocean Blvd		land across street from Odiorne
25-5	State of NH		? Ocean Blvd		land across street from Odiorne
25-6	Town Conservation Comission		? Pioneer Rd & Ocean Blvd		land behind the above
25-7	Town Conservation Comission		? Pioneer Rd & Ocean Blvd		land behind the above
25-8	Goustav Garceau	321 Pioneer	321 Pioneer		borders Seavey's Cr. (near clam bed
26-1	Florence H. Fitzpatrick	41 Harbor View	41 Harbor View		
26-2	Bradford F. Alden	35 Harbor View	35 Harbor View		

26-3	Lorette Carney	29 Harbor View	29 Harbor View		
26-4	George Hovanesian	23 Harbor View	23 Harbor View		
26-5	Albert D. Frisbee	17 Harbor View	17 Harbor View	new septic 1978	
26-6	Robert & Toby Jesurun	11 Harbor View	11 Harbor View		
26-7	Philip C. Hoyt	5 Harbor View	5 Harbor View		
26-8	Michael A. Bryan	51 Wentworth	51 Wentworth	new septic 1991	
26-9	William M. Binnie	35 Wentworth	35 Wentworth	relocated septic in 1994	permit for dredging & fill in 1994
26-10	William J. Cronin	33 Wentworth	33 Wentworth		
26-11	Francine S. Hall	29 Wentworth	27 & 29 Wentworth		
26-12	Gerard J. Terpstra	23 Wentworth	23 Wentworth		
26-13	Arthur W. Schlerper	PO Box 133 Portsmouth	21 Wentworth		
26-14	Paul Hansen	234 Parker Rd Goffstown	11 Wentworth		
26-15	Roberta K. Jennings	5 Wentworth	5 Wentworth		
26-16	Noele M. Clews	3 Wentworth	3 Wentworth		
26-17	Great Island Trust Co.	PO Box 245 Rye	? Wentworth		WBTS- 17785 sf
26-18	Great Island Trust Co.	PO Box 245 Rye	? Wentworth		WBTS- 21780 sf
Newcastle					
#1-1	State of NH		Clampit Island		vacant lot
#1-2	Katherine Campbell	92 Bridge St	92 Bridge St		
#1-3	Great Island Trust Co.	PO Box 246 Newcastle	? Bridge		WBTS
#1-4	Town of Newcastle		? Bridge St		
Map # 2	Great Island Trust Co.	PO Box 246	? Wentworth		
#3-1	Clifford & Margaret Heindel	129 Wild Rose Lane	129 Wild Rose Lane		ocean side
#3-2	Charles L. Thayer	330 Borthwicke Ave Ports.	149 Wild Rose		2 lots ocean side
#3-3	State of NH		Fort Stark		Historical Site
#3-4	Jack & Rebecca Beard	204 Wild Rose	204 Wild Rose		
#3-5	Joan H. Lockhart	174 Wild Rose	174 Wild Rose		
#3-7	Edward&Penelope Glassmeye	4 Coves End Rd Darien CT	? Wild Rose		
#3-8A	John B & Gladys L Smith	136 Wild Rose	136 Wild Rose		
#3-8B	Joan White	136 Wild Rose	136 Wild Rose		
#4-1	Crosby,Howard&Phyllis Trust		? Wild Rose		
#4-3	Wentworth BTS		housing development		24 lots, individually owned
#4-4	Loring & Lucille Larose	Wentworth Rd	? Spring Hill Rd		
#4-4A	Iren Crosby		? Spring Hill Rd		
#4-5	Lucille Larose	Wentworth	? Spring Hill Rd		
#4-6	Blair McCaferty	300 N River Rd Manchester	? Spring Hill Rd		
#4-7	Lucille Larose	Wentworth	? Spring Hill Rd		
#4-8	NSH Realty Trust	PO Box 10272 N Hampton	? Spring Hill Rd		

#4-9	Lucille Larose	Wentworth	? Spring Hill Rd		
#4-10	Ports. Marine Society	96 Spring Hill Rd	96 Spring Hill Rd		
#4-11	Lucille Larose	Wentworth	? Spring Hill Rd		
#4-12	Chester J. Fessenden	97 Spring Hill	97 Spring Hill		
#4-13	Lucille Larose	Wentworth	? Spring Hill		
#4-14	Micael P. Larose	102 Lavender Rd	102 Lavender Rd		
#4-15	Lucille Larose	Wentworth	? Lavender Rd		
#4-16	Stephen D & Judith Sawyer	PO Box 318 Newcastle	? Lavender Rd		
#4-17	Lucille Larose	Wentworth	? Lavender Rd		
#4-18	Lucille Larose	Wentworth	? Lavender Rd		
#4-19			? Lavender Rd		
#4-20			? Lavender Rd		
#4-21			? Lavender Rd		
#4-22	Margaret M. Fish	68 Spring Hill Rd	68 Spring Hill Rd		
#4-23					
#4-24	Sylvia Tabbutt	55 Pitt Lane Newcastle	48 Spring Hill Rd		
#4-25	Lucille Larose	Wentworth	? Spring Hill Rd		
#4-26	Thomas & Mary Lambert	Newcastle Rd	? Wentworth Rd		
#4-27	Wentworth BTS		small island		vacant lot
#5-1	Margaret Harford	92 Wild Rose	92 Wild Rose		
#5-2	Stuart & Donna Levenson	10 Meadow Ln N Hampton	56 Wild Rose		
#5-3A	Ahdrah Moore	350 Wentworth	350 Wentworth		
#5-3B	John & Meryl Walsh	300 Wentworth	300 Wentworth		
#5-4	Charles & Barbara Brown III	320 Wentworth	320 Wentworth		
#5-5	Thomas & Patricia Roy	314 Wentworth	314 Wentworth		
#5-6	Louise Kenneth & Erik Aspen	266 Wentworth	258 Wentworth		
#5-7	Louise Kenneth & Erik Aspen	266 Wentworth	266 Wentworth		
#5-8	Secret Pond Realty	254 Wentworth	254 Wentworth		
#5-9	Louise Kenneth & Erik Aspen	266 Wentworth	252 Wentwworth		
#5-10	Michael & Barbara Kuchtey	250 Wentworth	250 Wentworth		
#5-11	Thomas & Theresa Golter	238 Wentworth	230 Wentworth		
#5-12	Christopher&Stephani Mullin	Webster Grove MO	244 Wentworth		
#5-13	Town of Newcastle		Newcastle Commons		
#5-14	Carolyn Baker	9 Wild Rose	9 Wild Rose		ocean side
#5-15	George W. McLaughlin	91 Wild Rose	91 Wild Rose		ocean side
#5-16	Gertrude McCarthy	75 Wild Rose	75 Wild Rose		ocean side

Appendix C:

Bacterial Indicator Concentrations in Water at Sites Around Little Harbor.

Microbiological analysis of water samples included tests for fecal coliforms, *Escherichia coli*, enterococci, and *Clostridium perfringens*. Fecal coliforms, *E. coli*, enterococci and *C. perfringens* were measured using standard membrane filtration methods. Water samples for fecal coliforms and *E. coli* analyses were filtered on 0.45 µm membrane filters and incubated on mTEC agar media for 24 h at 44.5±0.2°C. Yellow colonies were counted as fecal coliforms, and those that remained yellow after incubation on urea-soaked pads were considered *E. coli*. Enterococci colonies were measured by incubating 0.45 µm membrane filters on mE medium at 41°C for 48 hours. At that time, the reddish-brown colonies that caused a black precipitate to form when filters were transferred to EIA agar were counted as enterococci. *C. perfringens* colonies were enumerated by filtering water through 0.7 µm filters and incubating the filters on mCP agar 24 h at 44.5±0.2°C in an anaerobic chamber under hydrogen and carbon dioxide. Large, flat, creamy, brownish colonies were counted as *C. perfringens* colonies, and were confirmed by looking for a pink-mauve color upon exposure to ammonium hydroxide fumes.

Fecal coliforms are the standard indicator for shellfish-growing waters in New Hampshire based on recommendations by the National Shellfish Sanitation Program, *E. coli* is the recreational standard for freshwater in New Hampshire and is the actual target organism of fecal coliform tests. Enterococci is the standard indicator for the estuarine recreational waters of New Hampshire, and *C. perfringens* is a spore-forming bacterial species that is an indicator of long-term fecal contamination and is being used with increasing frequency in related studies.

The data for fecal coliforms are presented in the main text of this report. Data for the other three bacterial indicators are presented in Tables C1-C3. The geometric means of the data for all four indicators and all sites are shown in Figures C1 and C2. Enterococci, fecal coliforms and *E. coli* exhibited similar spatial responses,, with the highest levels found upstream in Witch Creek, relatively high levels in Berry Brook, lower levels at Seavey and Sagamore Creeks, the Little Harbor bridge and the marina, and the lowest levels at the mouth of the harbor. *C. perfringens* concentrations were relatively low, and were highest at Sheafe's Point, which had the next to lowest levels for the other indicators. The paired data for all four indicators were compared to determine if different fecal indicators gave consistent indications of contamination. The results are summarized as correlation coefficients, as follows:

	FC	Ec	Ent	Cp
Fecal coliforms (FC)	1.000	0.974**	0.890**	0.071ns
E. coli (Ec)		1.000	0.952**	0.278*
Enterococci (Ent)			1.000	0.277*
C. perfringens (Cp)				1.000

* significance probability: <0.05
** significance probability: <0.01
ns: not significant (P>0.05)

The statistical analysis suggests that there are strong relationships between fecal coliform, enterococci and *E. coli* data. The relationship be *C. perfringens* data and both *E. coli* and enterococci data are much weaker, and there is no apparent relationship between *C. perfringens* and fecal coliform data. Thus, all three indicators used by the State of New Hampshire gave similar indications of fecal contamination, both from geometric mean trends and from direct relationships between data.

Table C1. Concentrations (per 100 ml) of E. coli in water samples from Little Harbor, 1995-96.

E. coli

Date	T1	T6	T7	T8	T13	T14	LH2	WC1	WC2	WC5	WC6	PC1	PC2	PC4	PC5	SC1	SC2	WRS1
7/20/95	1		2	15	35	0.5	46.5	5										
8/3/95	6		45.5	20	230	20.8	97.5	38										
8/7/95			126		10													
8/22/95					3	1.5	3.75											
9/15/95	1	1	1	2	1.5	3.5	17	1										
9/21/95	0.9	1	0.9	0.9	5	2	1	6										
10/5/95	0.9		0.9	130	0.9	0.9	0.9	0.9										
11/15/95	60	120	920		380	780	236	3250										
2/27/96	0.5	5.5	4	11	1	1	3.5	130										
5/9/96	9	11			20	20												
5/28/96	0.5	2.5			1		3											
5/30/96	3	6	250		5	12.5	2.5	52										
6/10/96	0.4	4	122		3.5	18	3	34	2	1.8	4	2	2					
6/18/96	9.5	19	52		5.5	12.5	23	10				3	0.9	2	4	2	2	6
6/25/96	0.5	1	24		2	5	1.5	12										
Geometric mean	1.9	4.9	18.2	9.6	6.7	6.2	7.3	18.6	2.0	1.8	4.0	2.4	1.3	2.0	4.0	2.0	2.0	6.0
Standard deviatioı	4.6	4.6	11.4	5.9	6.5	7.0	6.0	10.1										

Table C2. Concentrations (per 100 ml) of enterococci in water samples from Little Harbor, 1995-96.

Enterococci

Date	T1	T6	T7	T8	T13	T14	LH2	WC1	WC2	WC5	WC6	PC1	PC2	PC4	PC5	SC1	SC2	WRS1
7/20/95	0.25		2	2	3	3	3	5										
8/3/95	3		16.25	5.5	4	8.75	5.25	54.25										
8/7/95																		
8/22/95					2.75	3	0.25											
9/15/95	0.5	2	1.5	6	2	6.5	9.5	12										
9/21/95	2	1.5	0.5	28	11.5	1	5.5	9										
10/5/95	0.9		25.5	26	5.5	22.5	6.5	70.5										
11/15/95	60	231	1140		530	720	373	2000										
2/27/96	4	5	10	6.5	2	5	8	24										
5/9/96	0.5	2.5			11.5	4.5												
5/28/96	1	0.4			1.5		1											
5/30/96	0.4	0.5	7.5		1	3	1.5	12										
6/10/96	1	0.5	6.5		3	5	0.5	1.5	3.5	133	1	19.5	3.5					
6/18/96												6	0.5	2	4	2	2	6
6/25/96																		
Geometric mean	1.4	2.3	8.9	8.2	5.0	7.2	3.9	23.0	3.5	133.0	1.0	10.8	1.3	2.0	4.0	2.0	2.0	6.0
Standard deviatioi	4.6	7.9	9.1	2.8	5.2	5.5	6.9	7.4										

Table C3. Concentrations (per 100 ml) of C. perfringens in water samples from Little Harbor, 1995-96.

C. perfringens

Date	T1	T6	T7	T8	T13	T14	LH2	WC1	WC2	WC5	WC6	PC1	PC2	PC4	PC5	SC1	SC2	WRS1
7/20/95	0.5		2	3	6.5	2.75	2.75	15										
8/3/95	2.75		0.75	5	1.75	6.5	2.5	4										
8/7/95																		
8/22/95					4.5	2.5	1.5											
9/15/95																		
9/21/95	2	9	0.5	1.5	23.5	2	1	3.5										
10/5/95	2		2.5	7.5	2.5	10	1	11										
11/15/95	5	3.5	17.5		22.5	15	17.5	47.5										
2/27/96	4.5	5	6	6.5	1.5	6	8	2										
5/9/96	5	12			6	6												
5/28/96	26	46			7.5		2.5											
5/30/96	8	128	4		21	12.5	2.5	31.5										
6/10/96	4	1.9	0.9		12	4	0.5	8	16	2	16	4	1.9					
6/18/96	0.9	18	1.5		14.5	5	3.5	2.5				0.4	2.5	3.5	9.5	1	0.5	5
6/25/96	4	10	2		4.5	9.5	7.5	9										
Geometric mean	3.3	11.6	2.2	4.1	6.9	5.7	2.6	8.1	16.0	2.0	16.0	1.3	2.2	3.5	9.5	1.0	0.5	5.0
Standard deviatioı	2.8	3.6	2.9	1.9	2.6	1.9	2.7	2.9										

Figure C1. Geometric mean fecal coliforms and E. coli at sites in and around Little Harbor, 1995-96.

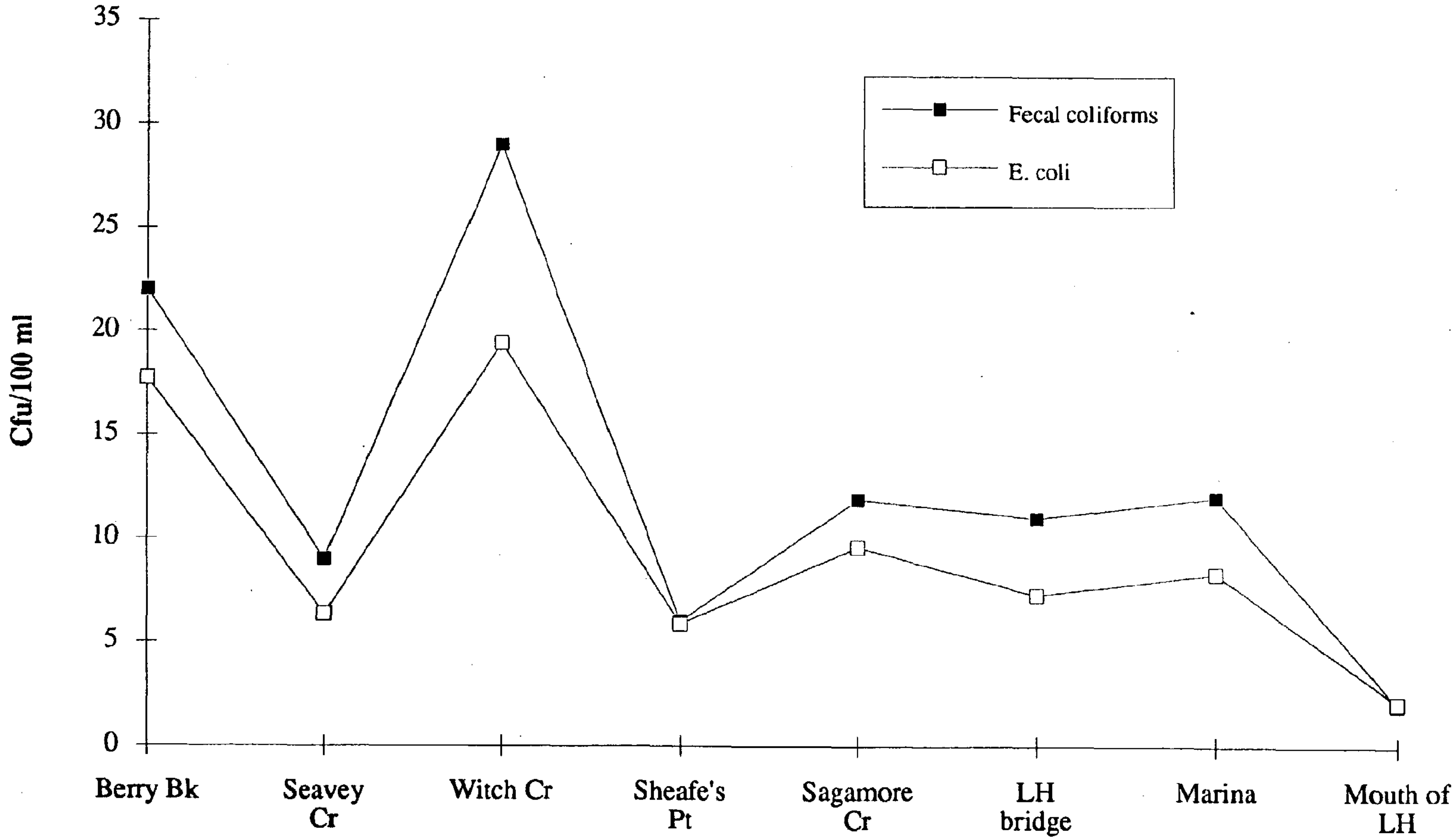


Figure C2. Geometric mean enterococci and C. perfringens at sites in and around Little Harbor, 1995-96.