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An Action Plan for the Taunton River Watershed:
Assessement and Recommendations

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An Action Plan for the Taunton River Watershed was prepared through a cooperative effort by the Commonwealth of Massachusetts and the State of Rhode Island. The one-year study was supported by an interstate grant under Section 309 of the federal Coastal Zone Management Act awarded to the Urban Harbors Institute at the University of Massachusetts at Boston on behalf of the Massachusetts Coastal Zone Management Office and the Rhode Island Coastal Resources Management Council.

The purpose of the study was to identify the major sources of pollution in the watershed, quantify the relative contributions, and to propose an action plan for initiating and guiding an implementation program to control the significant sources of pollution to the Taunton River and Mt. Hope Bay.

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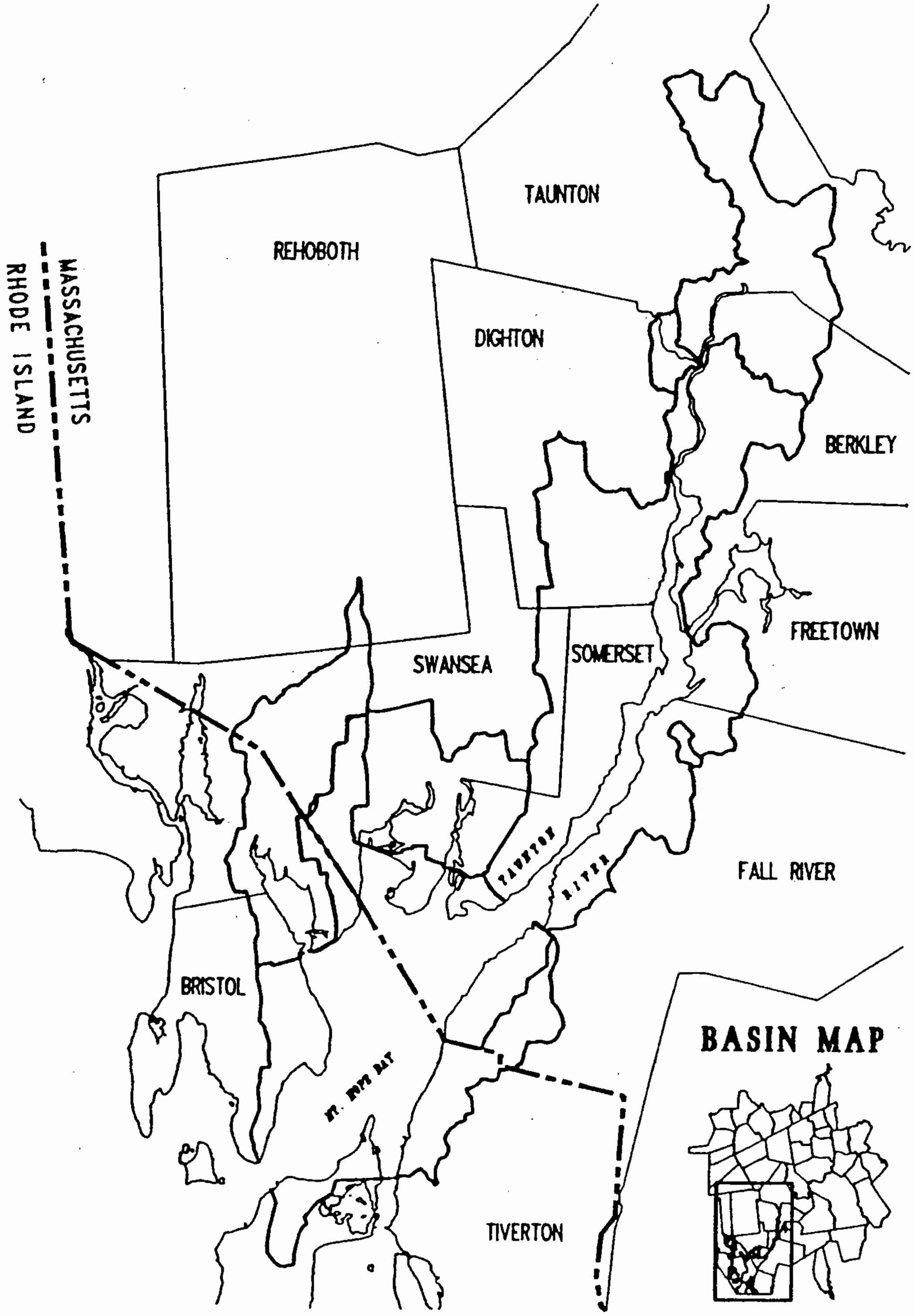


Map 1. Taunton River Watershed Study Area.

General Description of the Mount Hope Bay Estuary

The Mount Hope Bay estuary, as described for the purposes of this assessment, includes the tidal portion of the Taunton River, which extends to the city of Taunton, Massachusetts, and Mount Hope Bay, an embayment of Narragansett Bay. Mount Hope Bay has a surface area of 35.2 km2, 46 km of shoreline, an average depth of 5.7 m, and a total volume of 2.02 x 108m3 (Chinman and Nixon 1985). Seventy percent of the bay is within the state of Rhode Island, while 30% is contained in the state of Massachusetts. The major tributary to Mount Hope Bay is the Taunton River, which originates in Massachusetts and provides an estimated 85% of the total yearly freshwater input to the Mount Hope Bay estuarine system (Table 1). Three major tributaries provide freshwater to the tidal portion of the Taunton River; Three Mile River, Segreganset River, and Assonet River.

Since colonial times, the estuary and bay have been heavily used as a site for maritime commerce and industrial development. The locus of much of the development and growth that occurred along the shores of Mount Hope Bay has been within the city of Fall River. Fall River, located on the eastern shore of Mount Hope Bay, remains the major metropolitan area in the Mount Hope Bay coastal zone, but many of the original industrial sites were abandoned as the production of textiles and woven goods in the northeast declined. Today, many of the old textile mills have been renovated as clothing and textile outlets, and historic sites. The city of Fall River maintains an active shipping port, which receives approximately 50% of tanker traffic entering Narragansett Bay.

Table 1. Sources of freshwater to the Mount Hope Bay estuary, giving estimated input and percent of total input by source.

Source	Freshwater Input (liters per year)	Percent of Total Input
Taunton River[1]	5.99×10^{11}	85
STPs[2]	5.51×10^{10}	8
Industry[2]	1.35×10^{9}	<1
CSOs[3]	3.56×10^{9}	<1
Rainfall[4]	4.93×10^{10}	7

[1] Pilson and Hunt (1989).

[2] NPDES (1990).

[3] Maguire Group (1987).

[4] Estimated from surface area (Chinman and Nixon 1985) and average rainfall at Taunton, MA (Pilson 1989).

For the most part, the following description of the physical and chemical characteristics of Mount Hope Bay have been constructed from data reported in the Quarterly Reports of Marine Research Inc. (MRI), which samples several stations in Mount Hope Bay as part of the monitoring program for the Brayton Point Power Plant. All of the data presented from the MRI Quarterly Reports are for Station F, which is located just to the north of Spar Island (Map 2). This station was chosen to represent Mount Hope Bay because it is not in an immediate region of anthropogenic input to the bay, and can be considered an integrator of overall conditions in the bay. The sampling record for Station F also provides a consistent long-term data set. Further information than is presented here for the Spar Island data set is presented in a report on Narragansett Bay by Desbonnet and Lee (1991). Bacteriological data for portions of Mount Hope Bay and the Kickamuit River are taken from Rhode Island Department of Environmental Management (RIDEM) monitoring surveys. Data for the tidal portion of the Taunton River are mainly taken from studies performed by Boucher (1991), and Dorfman (1989). It should be noted however, that eight months of the Boucher study encountered near drought conditions, and the results may not be representative of "average" conditions in the tidal Taunton River and Mount Hope Bay. Further information for the tidal portion of the Taunton River are taken from Massachusetts Department of Environmental Protection (MADEP) monitoring surveys and special studies.

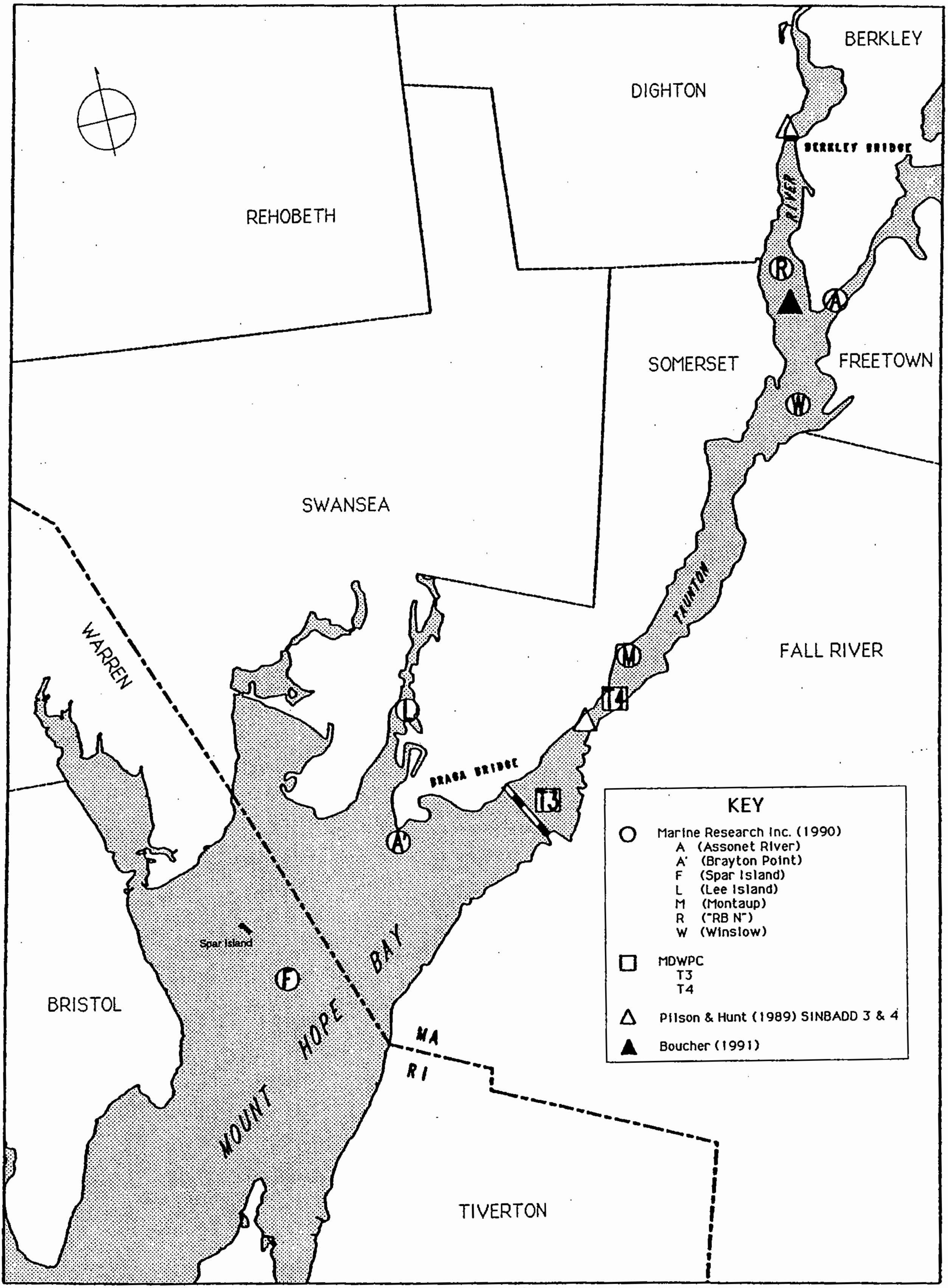
Water Temperature

Water temperature in the Mount Hope Bay estuary is typical of that seen in many New England estuaries. In Mount Hope Bay, water temperature varies seasonally, from lows in January when surface temperatures average 2.4°C, to highs in August when surface temperatures average 23°C (Figure 1). Only slight difference in temperature is noted between surface and bottom waters seasonally, indicating that the bay is generally not thermally stratified between October and February. Thermal statification of the water column may occur between March and September, but the extent and persistence of this is not fully known. Up estuary, in the tidal Taunton River, seasonal water temperatures during 1988–1989 varied from a low of 2.3°C in February to a high of 30°C in August (Figure 2). As in Mount Hope Bay, only slight difference is noted between surface and bottom water temperatures on a seasonal basis.

Over the 19–year MRI period of record for Mount Hope Bay, there is a long—term decrease in water temperature for averaged annual values in Mount Hope Bay . This trend is opposite that seen in nearby Narragansett Bay, and may reflect changes in the Brayton Point thermal effluent over time (Desbonnet and Lee 1991). The long—term average annual surface water temperature is 16.7°C, with a range of -0.7°C to 28.0°C. Bottom water temperature averages 15.2°C, with a range of -0.5°C to 26.9°C.

Salinity

Some seasonality is seen in monthly averages of surface salinity; less salty in spring months (24.6‰—March) and saltiest during the fall (28.9‰—October; Figure 3). Differences between surface and bottom water salinity suggests that stratification of the water column occurs, but is less pronounced during July, August, and September when freshwater input is generally at its seasonal low. Long-term salinity records for Mount Hope Bay show no apparent



Map 2. Sampling Stations in Mt. Hope Bay and Taunton River.

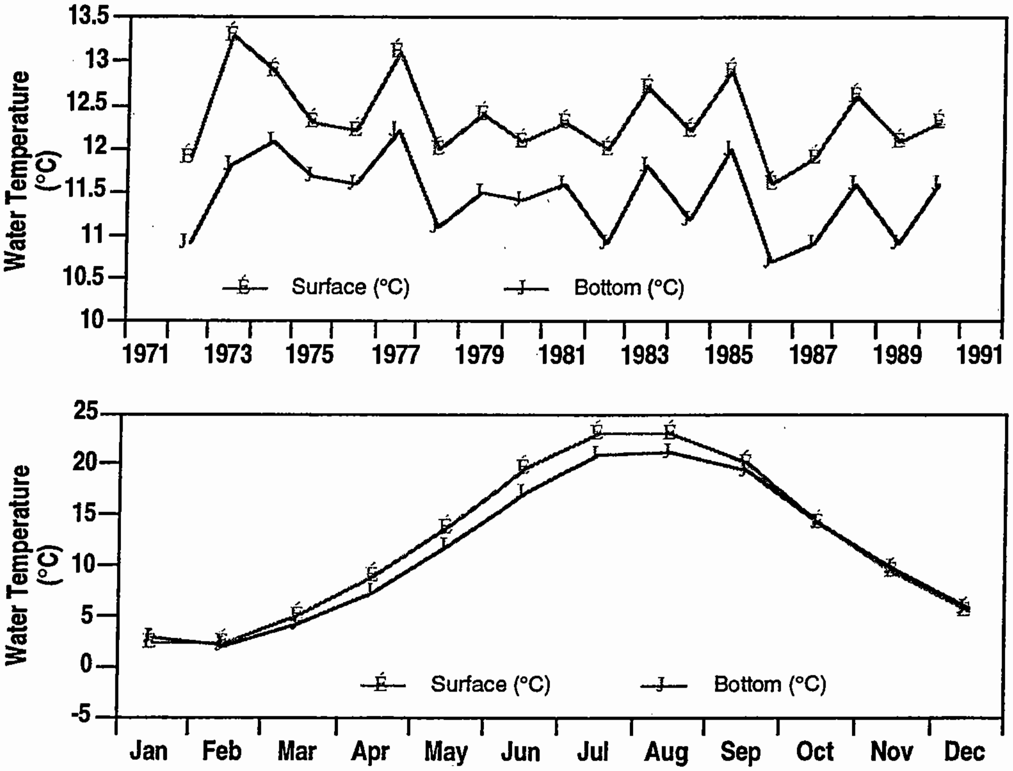


Figure 1. Long-term time weighted average annual and seasonal surface and bottom water temperature patterns at Spar Island in Mount Hope Bay. Average annual temperatures show a long—term decrease over time for both surface and bottom waters. Data from MRI 1972–1990.

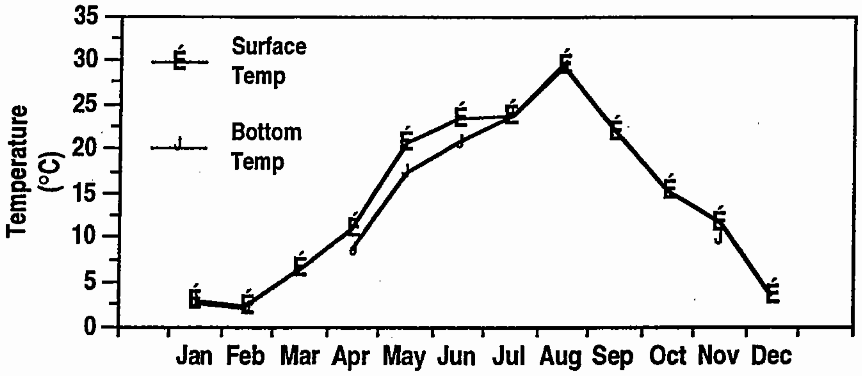


Figure2. Surface and bottom temperatures in the tidal Taunton River as measured by Boucher (1991) during the 1988–1989 season. The pattern suggests that thermal stratification of the water column is not a regular event.

increase or decrease over time (**Figure 3**). Long-term surface salinity is 27.1‰ (range of 8.8–33.8‰), while the long—term bottom salinity is 29.5‰ (range of 19.6–34.4‰).

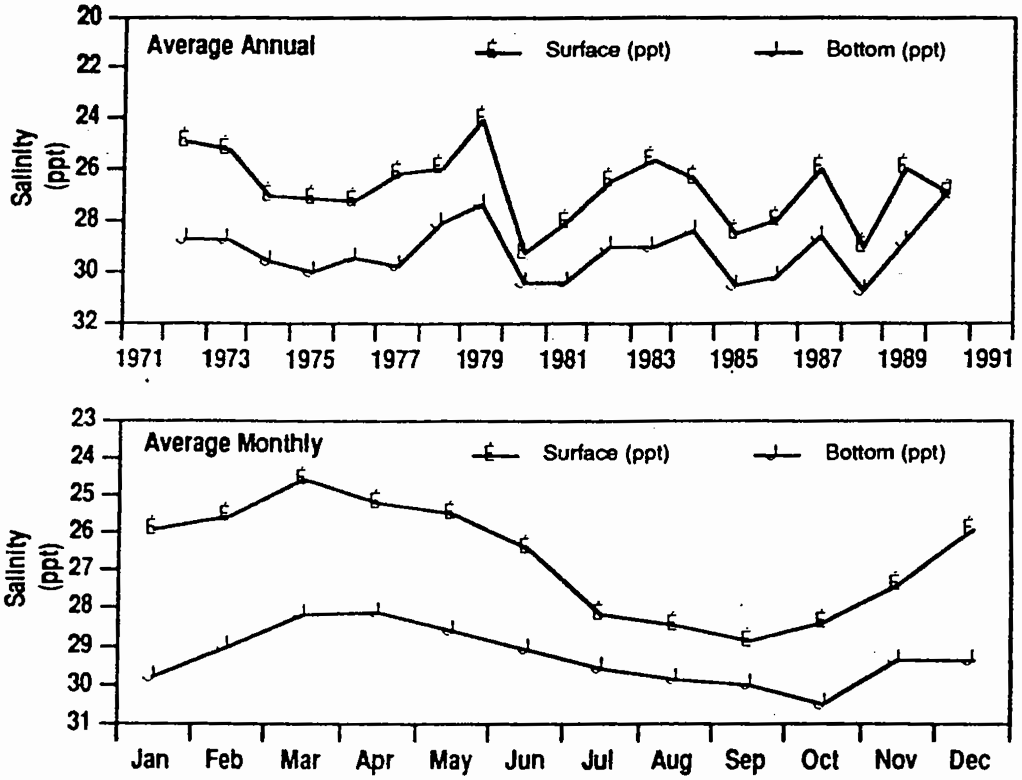


Figure 3. Long-term time weighted average annual and seasonal surface and bottom water salinity patterns at Spar Island in Mount Hope Bay. No long—term trend is noted for bottom water salinity between 1972 and 1990, but a slightly increasing trend in salinity is noted for surface waters. The seasonal trend suggests that density stratification occurs throughout the year, but less pronounced during summer months. Data from MRI 1972–1990

A similar seasonal pattern is seen for salinity variations in the tidal portion of the Taunton River (Figure 4). In the tidal portion of the Taunton River, dramatic change in surface salinity is noted in a down estuary transect (**Figure 5**). This region of the estuary is partially mixed, being characterized by periods of vertical mixing and periods of stratification, which drives the estuarine circulation in the estuary. This also suggests that a salt wedge forms within the tidal portion of the riverine estuary, and that density stratification of the water column can be a prominent and persistent situation in the estuary (Boucher 1991). Boucher (1991) estimated that the residence time of water in the tidal portion of the Taunton River was 2.7 days during periods of low flow, and 1.3 hours during times of high freshwater input from the Taunton River. The movement of waterborne particulates is therefore strongly related to freshwater input to the estuary from the Taunton River. Density stratification within the estuary will affect not only the movement of particulates, but can play an important role in the formation of bottom waters that are reduced in their oxygen content.

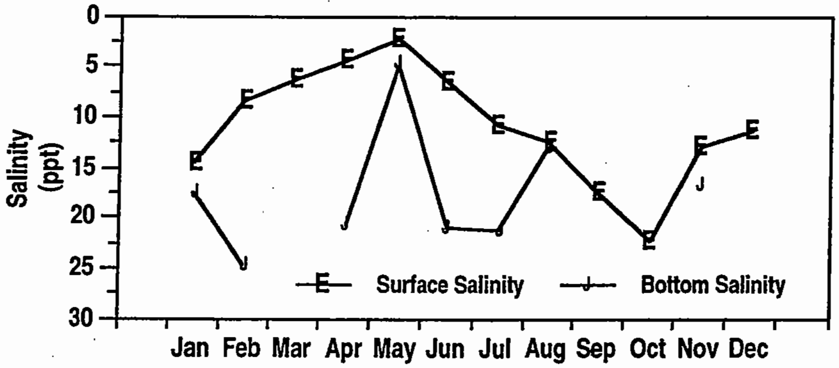


Figure 4. Seasonal surface and bottom salinity in the tidal Taunton River as recorded by Boucher (1991). The pattern suggests that density stratification occurs throughout much of the year, but is less pronounced during summer months.

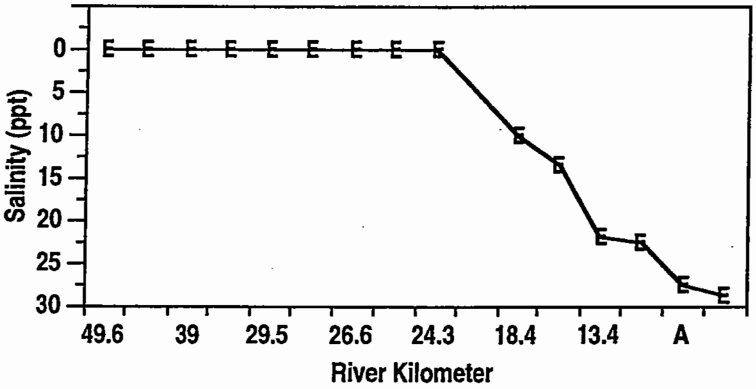


Figure 5. Surface salinity along a down estuary transect during July of 1986, showing a rapid mixing of the water column during July once within the tidal portion of the river. The pattern suggests that a salt wedge is present and that density stratification of the water column is occuring. Data from Dorfman (1989). A is above the Fall River STP discharge site, B is below. The vertical dashed line marks the head of tide and the approximate location of the city of Taunton, MA.

II. Sanitary Quality of the Mount Hope Bay Estuary

Bacterial contamination from sewage is the major water quality problem in the Mount Hope Bay estuary with regard to limitation of resource use by humans (Dixon et al #NBP-91-65). The principal source of fecal coliform contamination to the estuary are the Fall River CSOs (Maguire Group 1990, 1987; Rippey and Watkins 1987; Roman 1990). As a result of bacterial contamination, shellfishing beds in Mount Hope Bay have been closed for thepastfour decades, and arms of the bay, such as the Lee, Cole, and Kickamuit Rivers, have been closed during more recent times. Since the magnitude of coliform bacteria input from CSOs masks that of other sources, and because of the impacts of the loading, CSOs are the major focus for pollution abatement and clean up of Mount Hope Bay waters. Dry weather flow of CSOs was abated during 1991, and plans are presently under review to abate and control wet weather CSO discharges.

Fecal Coliform Bacteria and Pathogens

The presence of fecal coliform bacteria in estuarine waters is typically not an ecological threat. The presence of bacteria in the water column generally do not degrade conditions for the aquatic plants and animals inhabiting the area, and in some cases may provide an alternate food source for filter-feeding organisms. The presence of fecal coliform bacteria in the water column, however, does indicate that sewage, either treated or untreated, is entering the estuary. Other by-products introduced to the environment with sewage, such as nutrients, solids, and an oxygen demand, may influence the viability of the aquatic habitat in general. The major concern over fecal coliform contamination of the water column is the threat to human health. Fecal coliform bacteria, natural intestinal flora of warmblooded animals, are used as an indicator of potential human risk of disease contracted from pathogens associated with sewage wastes. High concentrations of fecal coliform bacteria indicate an increased risk of disease contraction from ingestion of contaminated water while swimming, or through the consumption of uncooked shellfish.

Fecal Coliform Loading

In the Mount Hope Bay estuary, the single greatest contributing source of fecal coliforms are the city of Fall River CSOs. These CSOs provide 98% of the total and control lable fecal coliforms entering the estuary over the coarse of one year (Table 2; Figure 7). The estimated 2000 boats docked and moored in the estuary, based upon a 120 day boating season, 25% occupancy rate, and other ISSC assumptions, account for the other 2% of the total and controllable fecal coliform load. The combined fecal coliform load from STPs and industry were less than 1% in light of other more significant sources.

A down-estuary transect of fecal coliform concentrations conducted during July of 1986 (Dorfman 1989), shows a generally decreasing trend in concentrations with distance down estuary (Figure 8). Nearly all samples taken during this survey exceed those considered safe for shellfishing. However, this study was conducted prior to the upgrade of the Somerset STP to correct problems with bacterial concentrations in its effluent, as well as before the dry weather Fall River CSO discharges had been corrected. The dry weather CSO flow may have been responsible for the elevated concentrations of bacteria noted in the region directly above the Fall River STP effluent discharge (Figure 8).

A recent survey by the Massachusetts Division of Marine Fisheries during March of 1991 (Churchill 1991), found concentrations to exceed 64 MPN at all but two sample stations in the tidal portion of the Taunton River. This study, however, was conducted after a rainfall event, and measured bacterial concentrations only to a minimum threshold of 64 MPN/100 ml. Therefore, the results of this study do not represent general conditions, but may, however, better reflect extreme conditions. The use of the minimum threshold bars direct comparison to the 1986 transect, and therefore the magnitude of the concentrations relative to location down estuary is lost.

Table 2. Total fecal coliform loading to the Mount Hope Bay estuary in numbers of bacteria per year, and percentage of total and controllable loadings.

Source	Loading By Source	Total Loadings	Percent of Total Loading	Percent of Controllable Loading[1]
STPs[2]		2.81×10^{13}	<1	<1
Somerset STP	2.03×10^{12}			
Taunton STP	4.87×10^{12}			
Fall River STP	2.12×10^{13}			
CSOs[3]		1.43×10^{16}	98	98
Industry[2]		1.42×10^{10}	<1	<1
Taunton River		na		
Runoff		na		
Sub-Taunton Runoff				
Sub-Mt. Hope Runoff				
ISDS		na		
Boats[4]		2.4×10^{14}	2	2
Marine Sources		na		
East Passage				
Sakonnet River				
Atmosphere		na		
TOTAL LOADING		1.46×10^{16}		

[1] Percent of controllable loading refers to all sources except for the atmosphere and marine sources.

[2] From NPDES records; EPA Region I (1990).

[3] From Maguire Group (1987).

[4] Estimated from ISSC model (US HEW 1988) based upon a 25% occupancy rate, 120 day boating season, and 2000 vessels (Amaral Pers Comm).

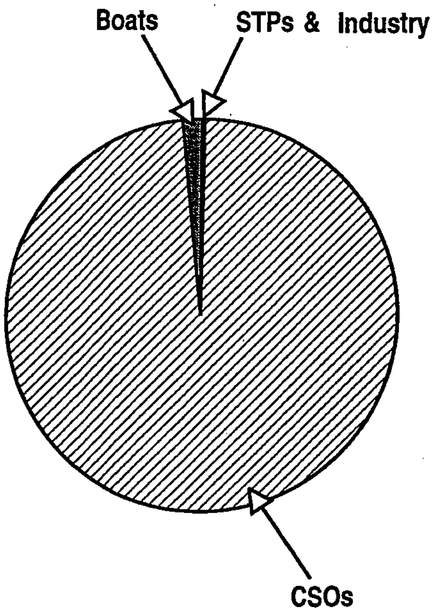


Figure 7. Contribution of fecal coliforms to the Mount Hope Bay estuary from controllable inputs. Data are from Table 2.

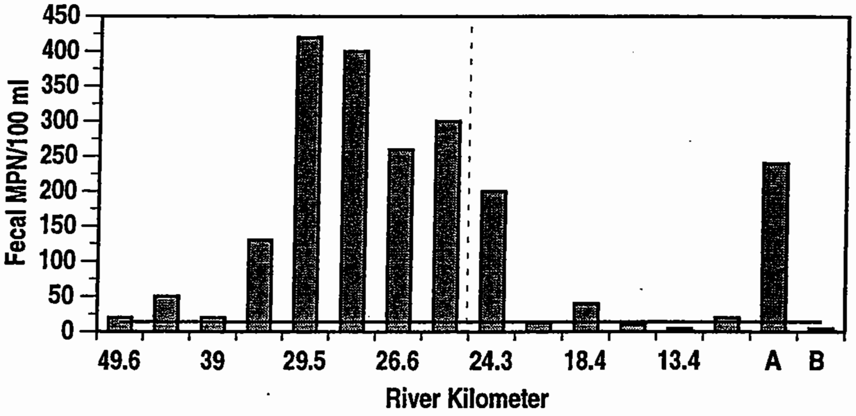


Figure 8. Fecal coliform concentrations along a down estuary transect during July of 1986. Solid line is the 14 MPN (RI; MA =15 MPN/100 ml)criteria for safe shellfishing for direct consumption. Data are from Dorfman (1986). A is above the Fall River STP discharge site, B is below. The vertical dashed line marks the head of tide and the approximate location of the city of Taunton, MA.

Data collected for Mount Hope Bay by the RIDEM Water Resources Division between 1986 and 1991 document that concentrations of fecal coliform bacteria have exceeded the levels considered acceptable for shellfishing on a fairly consistent basis throughout the Rhode Island section of Mount Hope Bay (RIDEM 1986–1991). The source of the contamination to Mount Hope Bay is not directly known, but bacterial concentrations are consistently higher after periods of rainfall. The bacterial sources are most likely a combination of urban runoff and CSO discharges (RIDEM 1990). Concentrations of fecal coliforms during dry weather periods generally are low, often meeting the criteria for the allowance of shellfishing in most of the Rhode Island portion of Mount Hope Bay. Rippey and Watkins (1987) suggested that the western portion of Mount Hope Bay could be open to shellfishing on a conditional basis. However, RIDEM has noted that the extreme variability in measured fecal coliform concentrations in the bay make it presently impossible to manage the resource for a shellfish harvest. If CSO discharges affect the bacterial quality of waters in western Mount Hope Bay, the abatement of the dry weather discharges from the Fall River CSOs may improve the probability of shellfishing on a conditional basis, but further study would be needed to document the impact of wet weather CSO discharges on the bacterial quality of the shellfish resource, as well as to identify other sources of contamination.

Although boats are estimated here as insignificant with regard to elevating fecal coliform concentrations in the water column when applied over the entire volume of the estuary, the impact of boating wastes on sanitary water quality could be significant on a local scale, particularly around marinas, mooring fields, docks, and within heavily used coves and bays. The potential impact of boat wastes on sanitary water quality of local sites are generally determined an a case by case basis according to the ISSC formula (US Dept. HEW 1988). However, documented boat use patterns at marinas and mooring fields are generally lacking, resulting in at best, guess work concerning the potential impact of boater wastes on local water quality. Clearly, better documentation of use patterns are needed on a local and/or regional basis, even in areas where boat waste pumpout facilities are located.

The input of fecal coliforms by STPs is presently masked by the influence of CSO discharges. It is therefore difficult to determine the effect of the STP discharges on water quality in the estuary with regard to bacterial contamination. The Fall River STP, the sewage treatment facility located closest to shellfishing areas in Mount Hope Bay, has a long-term loading record for fecal coliforms that shows a relatively constant level of bacterial discharge since the facility began operations as a secondary treatment facility in 1983 (Figure 9); the high load in 1984 was most likely due to initially unstable flow to the facility after upgrade completion and has skewed the seasonal pattern for March and June). Coliform loading does not increase with flow, suggesting that chlorination procedures undertaken at the facility are working to maintain low coliform bacteria levels in the effluent stream.

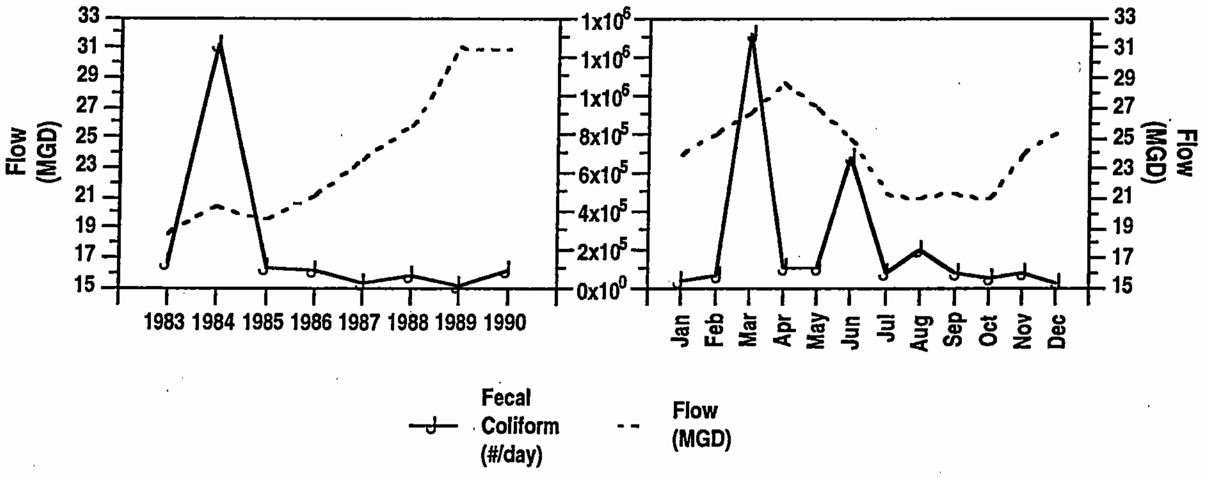


Figure 9. Average annual and seasonal patterns of loading for fecal coliforms from the Fall River STP 1983–1990. Flow discharge is plotted for comparison to loading values. Data from NPDES Permit Records, EPA Region I for the Fall River STP.

Once CSO discharges are abated, further study of bacteria concentrations in the Mount Hope Bay estuary will help identify other sources, such as STP input and urban runoff, quantify their magnitudes of input relative to each other, and their potential impact upon water quality. Management of shellfish resources in the estuary is therefore related to CSOs; it is nearly impossible to determine the impact of other sources on the potential for recreational shellfishing in Mount Hope Bay until CSOs are further controlled and abated.

Rippey and Watkins (1987) noted that the Taunton River provided 3% of the fecal coliform input of measured sources (CSOs, STPs) during wet weather, and 0.4% during dry weather. The Taunton River may therefore be a significant source of bacterial contamination to the tidal Taunton River and to Mount Hope Bay. These authors noted the Somerset STP to be a major source of fecal coliforms to the tidal Taunton River, a source which has since been further controlled and abated. More recent study needs to be performed in the upper estuary and non—tidal Taunton River to better predict the potential impact of the Taunton River as a source of fecal coliforms to Mount Hope Bay.

Water quality degradation also occurs in several arms of the bay, such as the Lee, Cole, and Kickamuit Rivers. A shoreline survey conducted in March 1990 by RIDEM provides several interesting points with regard to water quality in the Kickamuit River. The survey was conducted one day after 6 inches of rain was recorded in Fall River, and is therefore considered a show of extreme conditions rather than average conditions.

The survey concluded that Mount Hope Bay, urban runoff, and several feeder streams to the Kickamuit River were the main sources of contamination. Neither ISDS nor boats were considered to be causing the degraded water quality observed during the time of the survey. According to the results of the survey, circulation patterns and tidal currents in Mount Hope Bay move pollutants entering from the Taunton River and sources near the city of Fall River into the western portion of the bay. This water is then forced into the Kickamuit River on the flood tide, and during the time of the survey, contained high fecal coliform concentrations. On the ebb tide, as water moves out of the Kickamuit River, direct sources to the river (streams and runoff) become the predominant sources of coliform contamination. The final conclusion of the survey is that the Kickamuit River is not at present suitable for harevestable shellfish management because of the nature and variability of the bacterial sources.

If, indeed, Mount Hope Bay is a source of contaminants to the Kickamuit River, it is reasonable to believe that the same is generally true for the Lee and Cole Rivers. Abated dry weather flow from the Fall River CSOs, as well as planned abatement of wet weather discharge of CSOs, may reduce the impact that Mount Hope Bay has upon degrading water quality in the Kickamuit, and presumably in the Lee and Cole Rivers. However, in order to address the problems observed in these three arms of Mount Hope Bay, interstate effort and coordination will be required. The Kickamuit River Survey (RIDEM 1990) notes that high levels of coliform contamination enters the river from tributary streams that originate in Swansea, MA, further exemplifying the need for interstate management and cooperation.

Urban runoff may also contribute coliform bacteria to these waterways in large quantities and may be significant in its impact upon the documented degradation in these more localized areas. A more detailed effort to study and clearly identify the problems affecting water quality in the Lee, Cole, and Kickamuit Rivers is warranted. Studies should be coordinated on an interstate basis, and resultant management and action plans should be developed and implemented on an interstate cooperative basis. Every effort should be made to determine the impact of CSO discharges on the Lee, Cole, and Kickamuit Rivers, and attempt to predict the potential for shellfish harvest in these regions once wet weather CSO discharges are controlled according to the Phase II plan presently being reviewed. A reduction in bacteria in these arms of the bay will similarly reduce the potential contamination to Mount Hope Bay, and improve the probability of opening shellfish beds for harvest in all resource areas.

In summary, shellfishing in the Mount Hope Bay estuary system will remain an improbability until the wet weather CSO discharges are further controlled. The adoption and implementation of a CSO abatement plan should be the priority issue for action with regard to improving water quality and resource availability throughout the estuary. The EPA should continue its interaction with the city of Fall River to ensure completion of the planning process, as well as to ensure initiation of abatement actions. The city of Fall River should explore any and all avenues available in order to gain the required funding to implement abatement of the CSO problem. Further recommendations and initiatives specifically related to the abatement of the Fall River CSOs is to be found in CCMP (Narragansett Bay Comprehensive Coastal Management Plan) Section 04–01–04 Source Control: CSOs (I-IV). The recommendations contained in this section of the CCMP should be carried out by each of the state agencies as noted, and the detailed initiatives considered and carried out in a timely fashion.

RIDEM and MADEP, in conjunction with, or through, the Interstate Committee, should begin developing a plan of study within the estuary to document changes in water quality due to CSO abatement, to identify further sources of bacterial contamination to the estuary, and to develop abatement actions for identified sources that limit the potential for shellfish harvest in the estuary. The state agencies should coordinate their efforts simultaneously within the same region of the estuary, and cooperate to abate any and all identified sources that restrict shellfishing in that region. The state agencies should then jointly develop fisheries management practices, including the monitoring of waters in the estuary, to ensure interstate compatability in sustaining shared waters and resources. The regions of the estuary to recieve interstate focus should be, but not limited to, Mount Hope Bay, the tidal Taunton River, and the Lee, Cole, and Kickamuit River. The preceding are directly relevant to CCMP Sections 04–02–04 Public Health (I-II); 04–01–07 Source Reduction: NonPoint Source (I-IV); 04-01-04 Source Control: CSOs (I-IV), which should be reviewed and carried out by their respective state agencies.

State agencies, through the Interstate Committee, should develop a plan for the initiation of boat sewage pumpout facilities throughout the Mount Hope Bay estuary. Each state agency should develop a prioritized list of regions to implement pumpout facilities by identifying boater use patterns in respective state waters. The Interstate Committee should then review state pumpout priorities and plans to ensure that boaters will recieve equitable service, fees, and availability within the estuary. CCMP Section 04–01–06 Source Control: Boater Discharges, should be reviewed by each of the state agencies and the Interstate Committee, for implementation on a consistent basis throughout the estuary. The placement of pumpout facilities should take advantage of the location of existing sewer line to avoid on site storage where possible.

The Fall River STP, in response to potential increased demand for waste treatment, should review the infiltration and inflow problem, correcting the problem so that the facility will not exceed its functional capacity of 31.3 MGD in response to increased use of the sewer system.

III. BOD, TSS, and Dissolved Oxygen in the Mount Hope Bay Estuary

Overall, dissolved oxygen is not problematic in Mount Hope Bay and the tidal Taunton River (i.e., wide spread anoxic or hypoxic conditions not reported), but dissolved oxygen concentrations often fall below the EPA criteria required of Class SA and Class SB quality waters in bottom waters of the estuary. The failure to meet Class SA and SB water quality criteria in bottom waters of the bay and river is typical only of the summer months of June, July, and August. Dissolved oxygen concentrations throughout the water column generally meet the Class SA and SB criteria throughout the remaining months of the year. The cause of the low summer oxygen concentrations (natural; anthropogenic) is not clear, and the impact upon benthic fauna from these seasonal events is not known. The occurrance of low dissolved oxygen in the estuary is therefore a problem with regard to meeting mandates of the Clean Water Act, but the ecological implications are at present unknown.

BOD and TSS

BOD (biochemical oxygen demand) is a measure of the oxygen, usually over a 5 day period, required to convert and/or breakdown organic matter in water. The higher the BOD, the greater the oxygen consumption. Oxygen consumption is generally greatest in the region surrounding the point of discharge, but if oxygen is limiting, or if the oxygen demand is great, a wider area of receiving water will be required to meet the oxygen demand. If mixing, dilution, and aeration in receiving waters is good, the impact of the BOD load may be minimal. In those areas where physical processes such as mixing are reduced, BOD from the discharge of organic substances may result in degraded water quality conditions, often in the form of low oxygen waters. Within Mount Hope Bay, the potential impact of BOD may be addressed using a very complete record of dissolved oxygen concentrations measured over a 19-year period by Marine Research Inc. during their monitoring program for the Brayton Point Power Plant.

TSS (total suspended solids) is a measure of the solids present in the water. The proportion of measured solids that are organic will require oxygen during breakdown by physical and chemical means. Measures of solids in the water column also reflects upon the clarity of the water, giving some indication of light availability for aquatic plants. As TSS increases, oxygen consumption may increase during the consumption of organics, and water clarity and light penetration will decrease. No long-term data exist by which to assess the potential impact of TSS on water clarity in the estuary, and therefore the assessment of potential impacts upon the estuary from TSS loading is incomplete.

BOD Loading

Loading of BOD to the Mount Hope Bay estuary is dominated by the input of the three STPs within its confines. The three STPs contribute 38% of the total and controllable BOD input to the estuary (Table 3; Figure 10). Of the three STPs, the Fall River STP contributes 82% of the STP total, and has contributed an increasing BOD load to the estuary since 1982 (Figure 11). The Taunton STP provides 13% of the total BOD load contributed by STPs, and the Somerset STP 5%. The Taunton River supplies 32% of BOD to the estuary, generally because of its discharge volume, showing that its contribution of BOD is nearly equal to that of the three sewage treatment facilities. Calculated runoff loading to the estuary and CSO discharges respectively represent 16% and 12% of the total and controllable BOD input. Industry discharging to the estuary only contributes 2% of the total and controllable BOD load.

Table 3. Total BOD-5 loading to the Mount Hope Bay estuary in kilograms per year, and percentage of total and controllable loadings.

Source	Loading By Source	Total Loadings	Percent of Total Loading	Percent of Controllable Loading[1]
STPs[2]		1414017	38	38
Somerset STP	75010			
Taunton STP	184619			
Fall River STP	1154388			
CSOs[3]		499024	12	12
Industry[2]		69255	2	2
Taunton River[4]		1197200	32	32
Runoff[5]		590671	16	16
Sub-Taunton Runoff	466349			
Sub-Mt. Hope Runoff	124322			
ISDS		na		
Boats		na		
Marine Sources		na		
East Passage				
Sakonnet River				
Atmosphere		na		
TOTAL LOADING		3770167		

[1] Percent of controllable loading refers to all sources except for the atmosphere and marine sources.

[2] From NPDES records; EPA Region I (1990).

[3] From Maguire Group (1987).

[4] From the Taunton Watershed Alliance monitoring data for June 1991–February 1992 from their monitoring station 12 on the Taunton River.

[5] Estimated from Schueler (1987); RIGIS (1992); MAGIS (1992); see Appendix __ for concentration data sources used in the loadings model.

TSS Loading

The calculated load of TSS to the estuary is dominated by calculated urban runoff sources, which contributes 52% of the total and controllable TSS load (Table 4; Figure 12). The Taunton River, the second largest source of TSS, provides 32% of the total. STPs provide 12% of the total

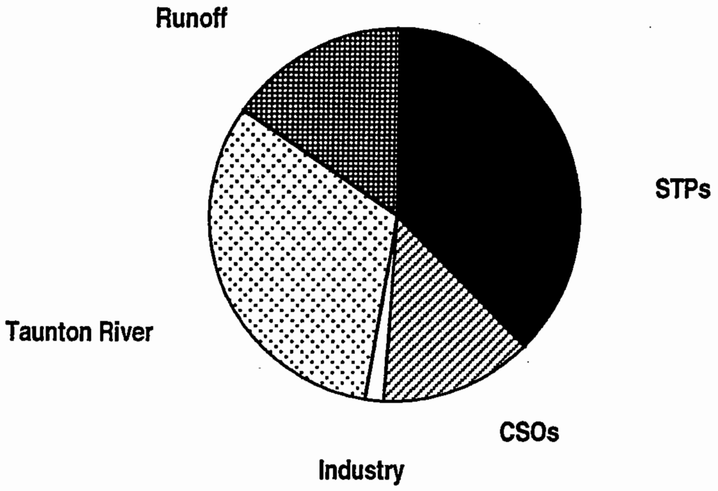


Figure 10. Contribution of BOD-5 to the Mount Hope Bay estuary from controllable inputs.

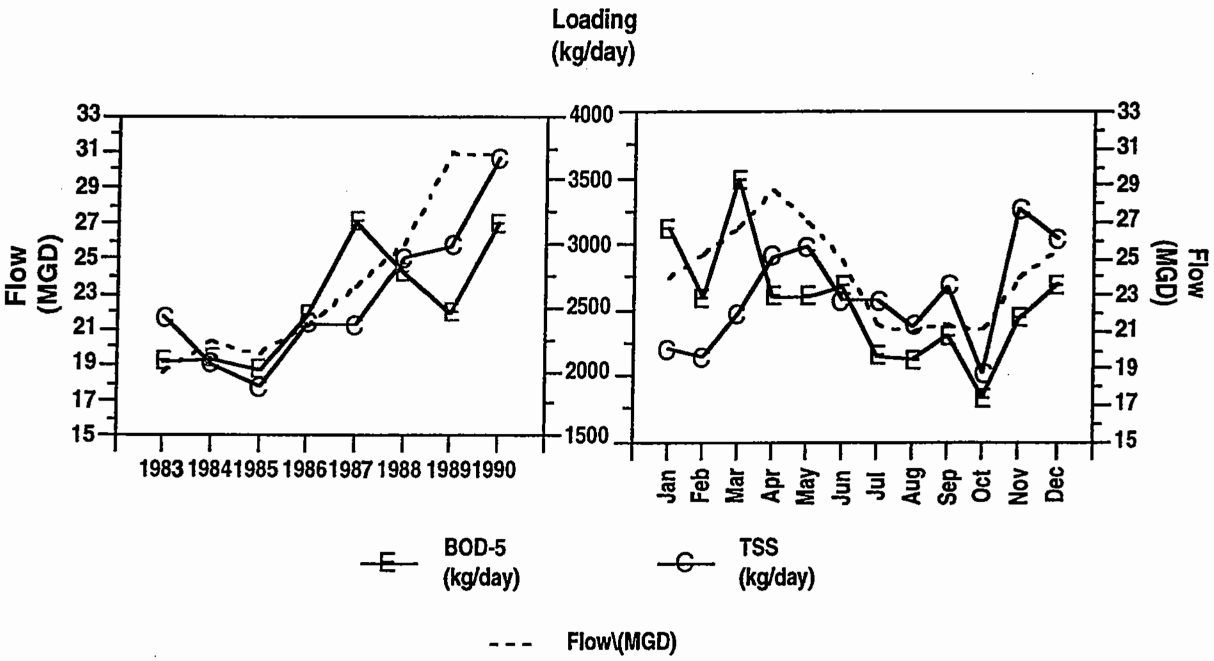


Figure 11. Average annual and seasonal trends for the discharge of BOD and TSS from the Fall River STP 1983–1990. Data from NPDES Permit Records, EPA Region I for the Fall River STP.

and controllable TSS load, with the Fall River STP contributing 86% of the STP loading. The load of TSS supplied by the Fall River STP has increased over time, very closely following the pattern of increase in discharge flow from the facility (Figure 11). The Taunton STP provides 11% of the STP load of TSS, and the Somerset STP 3%. CSOs provide 3% of the total and controllable TSS load, and industry only 1% of TSS loading.

Table 4. Total TSS loading to the Mount Hope Bay estuary in kilograms per year, and percentage of total and controllable loadings.

Source	Loading By Source	Total Loadings	Percent of Total Loading	Percent of Controllable Loading[1]
STPs[2]		1561595	12	12
Somerset STP	58028			
Taunton STP	164170			
Fall River STP	1339397			
CSOs[3]		392089	3	3
Industry[2]		76291	1	1
Taunton River[4]		4022592	32	32
Runoff[5]		6563015	52	52
Sub-Taunton Runoff	5181660			
Sub-Mt. Hope Runoff	1381355			
ISDS		na		
Boats		na		
Marine Sources		na		
East Passage				
Sakonnet River				
Atmosphere		na		
TOTAL LOADING				

[1] Percent of controllable loading refers to all sources except for the atmosphere and marine sources.
[2] From NPDES records; EPA Region I (1990).
[3] From Maguire Group (1987).
[4] Estimated from Pilson and Hunt (1989) concentration and flow data.
[5] Estimated from Schueler (1987); RIGIS (1992); MAGIS (1992); see Appendix __ for concentration data sources used in the loadings model.

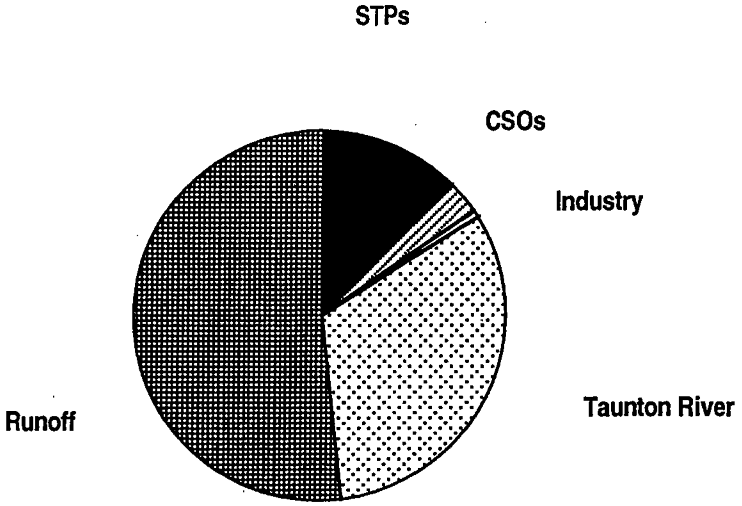


Figure 12. Contribution of TSS to the Mount Hope Bay estuary from controllable sources.

Dissolved Oxygen Conditions

Concentrations of dissolved oxygen exhibit seasonal fluctuations in the waters of Mount Hope Bay, and is more pronounced in bottom waters than at the surface (Figure 13). A similar pattern is noted for dissolved oxygen concentrations measured in the tidal portion of the Taunton River (Figure 14). Bottom water oxygen concentrations in Mount Hope Bay range from a seasonally averaged high of 11.1 mg l-1 in January, to a seasonally averaged low of 5.2 mg l-1 during July. Typical of New England estuaries, the Mount Hope Bay estuary is under its most stressed oxygen conditions during late summer when water temperatures are high and dissolved oxygen concentrations at their lowest of the seasonal cycle.

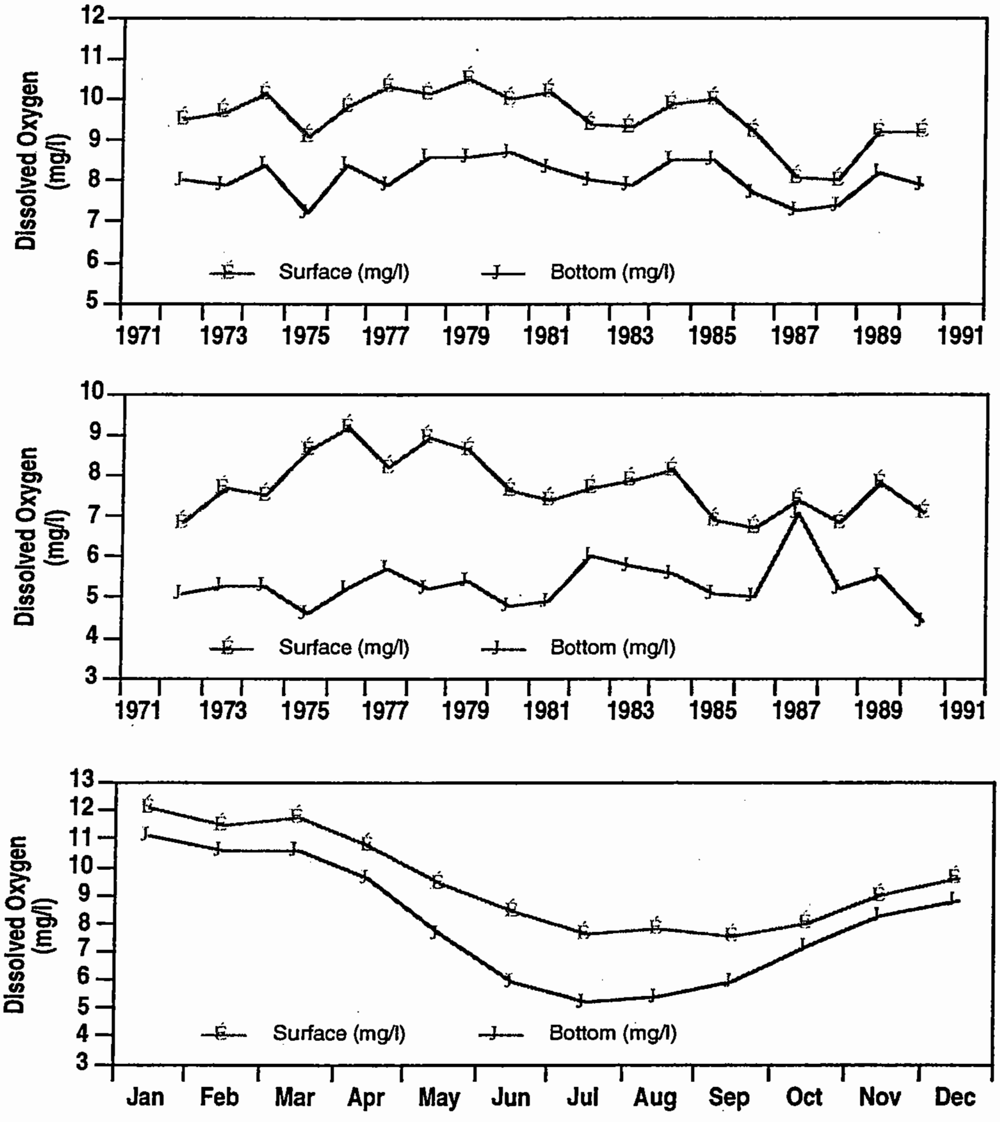


Figure 13. Long-term time weighted average annual and seasonal surface and bottom water dissolved oxygen concentrations as Spar Island in Mount Hope Bay. No Change in the long-term record is noted from 1972-1990 for surface and bottom waters annually, or for the month of August. Data from MRI 1972-1990.

Dissolved oxygen data collected by Dorfman (1989) for surface and bottom waters along a down estuary transect during July 1986 show an increase with distance down estuary, particularly once inside the tidal Taunton River, where mixing dynamics have a greater influence on the water column (Figure 15). Measurements of BOD along this same transect by Dorfman (1989) show that BOD concentrations are fairly regular throughout the non-tidal portion of the Taunton River, with increases in the regions of the estuaries STPs (km 24.3, 13.4, B) and CSOs (A; Figure 16). Dissolved oxygen content increases in the region of Fall River, despite a subsequent rise in BOD in the area, and probably due to the physical dynamics of the estuary such as winds, tides, and mixing.

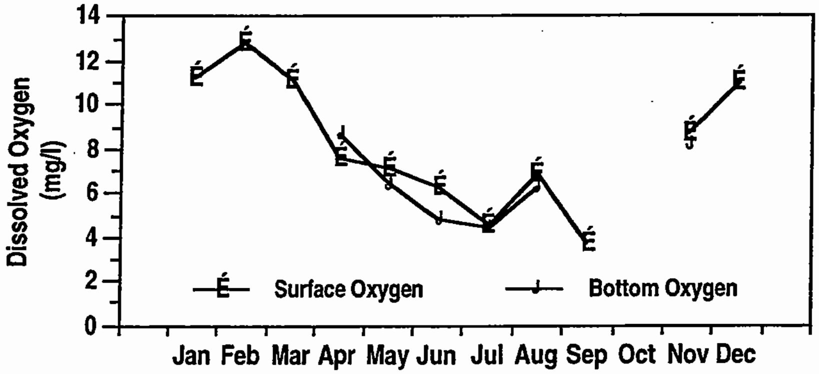


Figure 14. Seasonal dissolved oxygen concentrations in surface and bottom waters of the tidal Taunton River during 1988–1989. Data are from Boucher (1991).

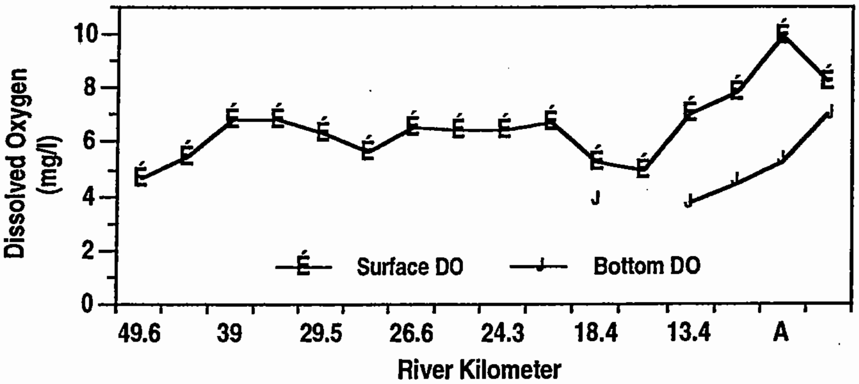


Figure 15. Dissolved oxygen concentrations in surface and bottom waters along a down estuary transect during July of 1986, showing increased values in the tidally mixed portion of the estuary. Data from Dorfman 1989. A is above the Fall River STP discharge site, B is below. The vertical dashed line marks the head of tide and the approximate location of the city of Taunton, MA.

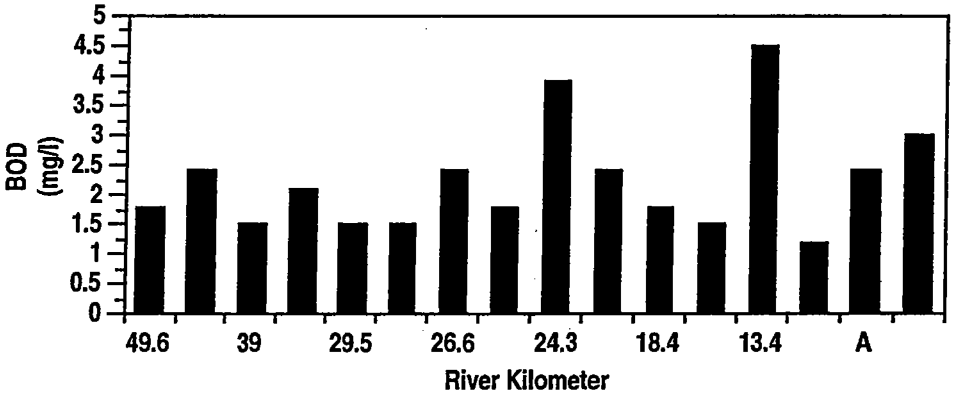


Figure 16. BOD concentrations along a down estuary transect during July 1985, showing predominant increases in the region of the areas STPs (km 243, 13.4, B) and CSO s (A). Data are from Darfman (1989). A is above the Fall River STP discharge site, B is below. The vertical dashed line marks the head of tide and the approximate location of the city of Taunton, MA. River kilometer 13.4 is in the vicinity of the Somerset STP discharge site.

None of the dissolved oxygen measures taken during this survey, however, show anoxic or hypoxic levels of oxygen. A more recent study in the tidal Taunton River by Dallaire (1992) found that 80% of sampled oxygen concentrations at two stations (Brightman St. Bridge; Braga Bridge) were below 5 mg l-1 from July through September in bottom waters. These studies clearly show that dissolved oxygen measures violate Class SA and Class SB water quality criteria routinely during summer months throughout the Mount Hope Bay estuary.

Long—term (19–year) average annual dissolved oxygen concentrations in the bay are 8.9 mg l-1 in surface waters (range of 16.8–4.3 mg l-1), and 6.9 mg l-1 in bottom waters (range of 14.7–1.2 mg l-1; Figure 13). Average oxygen concentrations in either surface or bottom waters have remained essentially constant for the past 19 years. There was a short—term decline between 1985 and 1988, increasing to the long—term average by 1990 (Figure 13). Similarly, long—term oxygen concentrations averaged annually for the month of August show no apparent trend over time (Figure 13).

Although no changes in dissolved oxygen concentrations over time are noted in averaged values, there have been changes in the frequency of low dissolved oxygen events in bottom waters of Mount Hope Bay. A plot of the occurrence of all bottom water dissolved oxygen data, in one-half mg l-1 increments, shows that the most common measures of dissolved oxygen in the bay are between 5.5 and 6.5 mg l-1 over the 19–year period of record (Figure 17). The occurrence of higher dissolved oxygen concentrations is definitely under–represented due to reduced sampling frequency from September through May. Because of this under representation of high oxygen concentrations, the mean value of dissolved oxygen in Figure 17 is skewed to the left rather than falling near the long—term average of 6.9 mg l-1 for bottom waters. However, June through August, the most heavily sampled months, is the time when low dissolved oxygen concentrations would be expected to occur, and provides a good basis for further analysis. The frequency of sampling changed over the 19–year record, decreasing from an average of 65 samples per year prior to 1977, to 42 samples per year beginning 1977. The

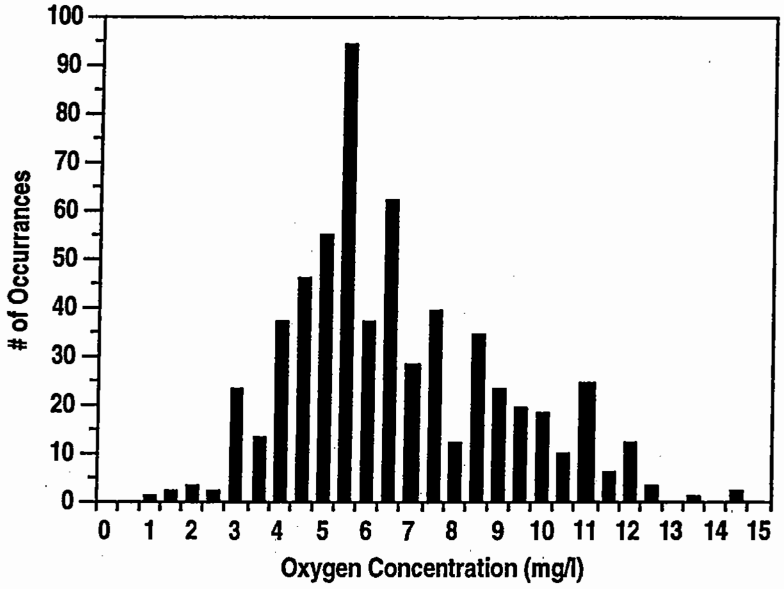


Figure 17. Number of occurrances of dissolved oxygen concentrations recorded in bottom waters at Spar Island, in 0.5 mg/l increments, between 1972 and 1990. Higher concentrations are under represented due to a reduced frequency of sampling during Sept–May. Mid to low concentrations are best represented as sampling frequency is greatest June through August. Data from MRI 1972–1990.

sampling frequency has generally remained stable since the change in frequencey between 1977 and 1978, with 44 sampling events in 1990.

The occurrence of dissolved oxygen measures less than 5.0 mg l-1 (Class SB criteria) is highly seasonal, being most frequent in June, July, and August (Figure 18). The occurance of oxygen concentrations less than 5.0 mg l-1 becomes less frequent over the 19–year record (Figure 19). Only very few occurrences of dissolved oxygen measures less than 3.0 mg l-1 (hypoxic) are to be found over the 19–year record (Figure 18), and none less than 1 mg l-1 (anoxic) are found. A total of 12 occurrences of oxygen concentrations less than 3.0 mg l-1 have occurred between 1971 and 1990, with only one occurrence of dissolved oxygen less than 3.0 mg l-1 recorded since 1984.

In order to check whether low dissolved oxygen events were related only to changes in temperature and salinity, percent saturation of oxygen in the water column was also calculated using the salinity, temperature, and oxygen content measures made by MRI between 1972 and 1990. Oxygen saturation is useful in determining how much oxygen is in the water column, relative to what could be, based upon temperature and salinity conditions.

Oxygen saturation conditions in the surface waters of Mount Hope Bay generally remain near or above 100% saturation (Figure 20). In surface waters, exposure to oxygen at the air—water interface, and having high concentrations of oxygen producing phytoplankton, often results in saturation exceeding 100%, a condition termed "super saturation." Poor saturation of water with oxygen is more typical of bottom waters, where oxygen input from the atmosphere is less pronounced, and where benthic fauna are actively consuming oxygen during metabolic processess.

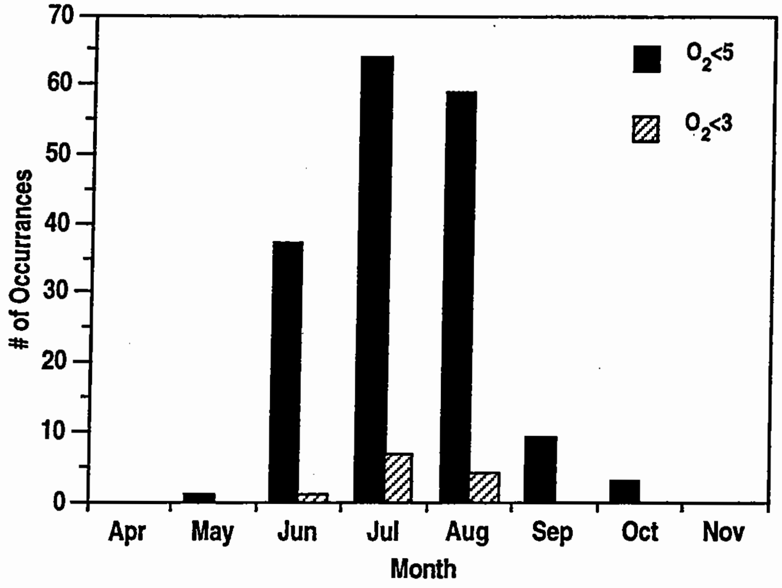


Figure 18. The seasonal occurrance of dissolved oxygen measures in bottom waters less than 5 mg/l, and less than 3 mg/l, as taken from the MRI Spar Island data set, 1972–1990.

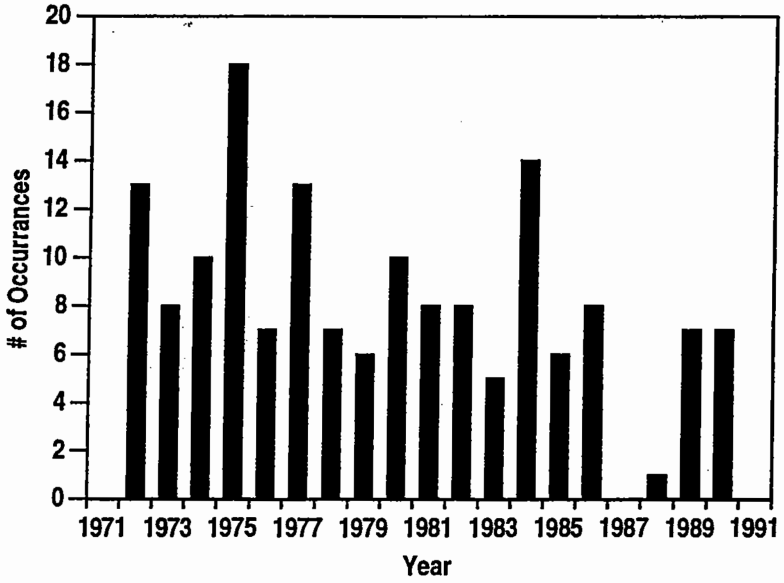


Figure 19. The frequency of occurrance of dissolved oxygen measures below 5 mg/l in bottom water at the Spar Island station in Mount Hope Bay from 1972–1990. Data from MRI 1972–1990.

On average, oxygen saturation tends to remain above 65% in bottom waters throughout August, and remain close to 80% on an average annual basis (Figure 20). No readily apparent long—term changes are noted for August or average annual values. Observation of the occurrence of oxygen saturation values below 80% (the average annual value at Station F), and 73% (the average August value at Station F) shows an overall decrease in occurrance between 1972 and 1990 (Figure 21). For both low oxygen saturation parameters, a decrease of about half is noted between the early 1970s and 1989–1990. This further suggests that conditions related to increased oxygenation of the water column are improving in Mount Hope Bay over time. As with dissolved oxygen concentrations, the greatest occurrence of low oxygen saturation in the water column occurs from June through August, with July having the greatest occurrence of poor saturation in the water column overall.

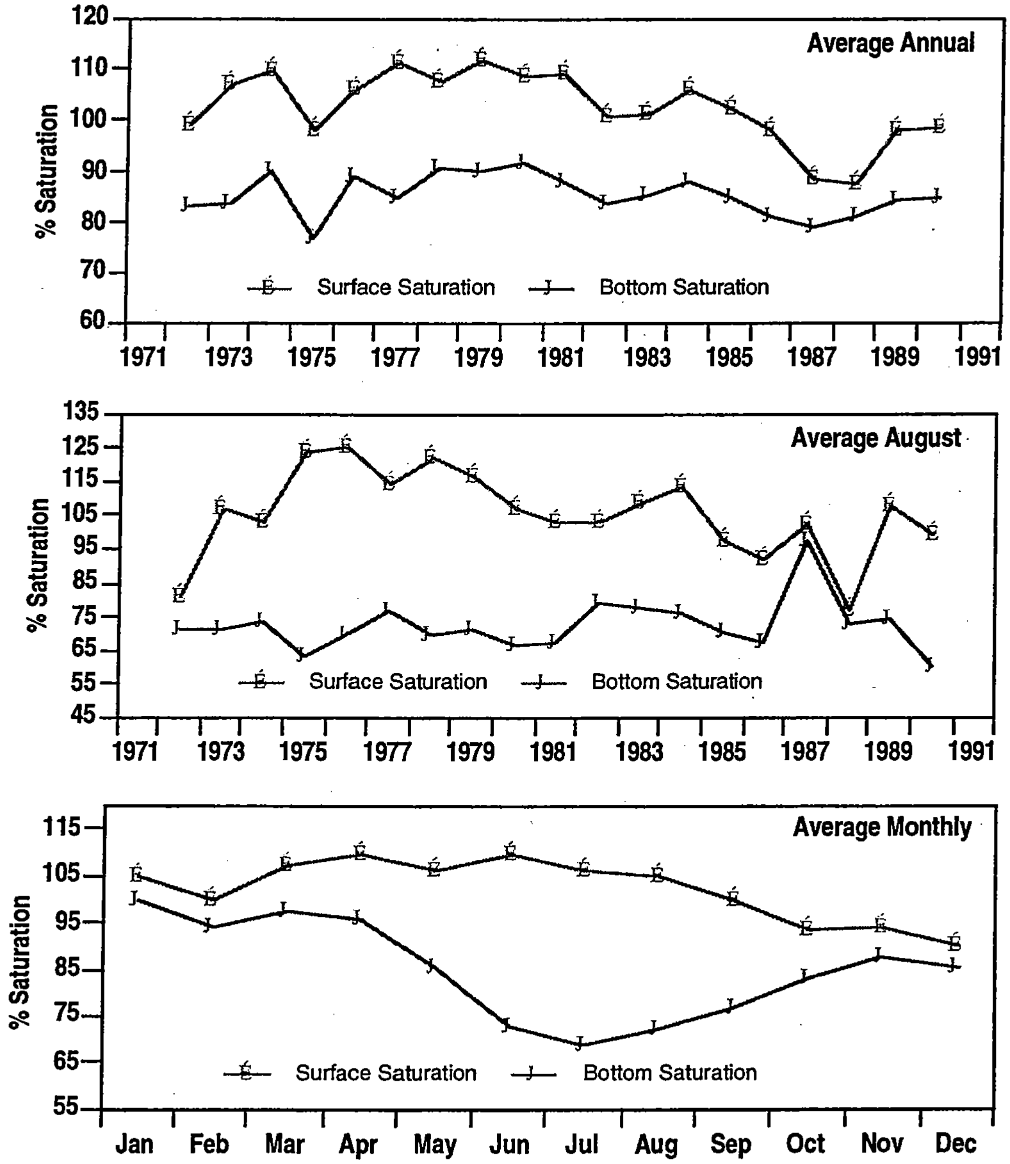


Figure 20. Long—term time weighted average annual and seasonal surface and bottom water percent saturation of oxygen at Spar Island in Mount Hope Bay. No long—term changes are noted between 1972 and 1990 for annual or August surface or bottom waters. The seasonal pattern shows that June through September are the months when oxygen saturation reaches its lowest levels. Data from MRI 1972–1990.

A 1990 study of dissolved oxygen concentrations in Mount Hope Bay conducted by the Massachusetts Department of Environmental Protection (MA DEP) shows results similar to those already noted. Oxygen concentrations generally remain above hypoxic levels (3.0 mg l-1) throughout the bay during the summer, with an occasional sample falling below 3.0 mg l-1, but not remaining so throughout a second sampling event. Gaps in the plots shown in Figure 22 represent missing data, not a measure of zero oxygen in bottom waters. Stations in the tidal portion of the Taunton River (Map 2; stationsT3:T4) also experienced dissolved oxygen measures less than 5.0 mg l-1 during summer months, but concentrations did not become anoxic or hypoxic at these stations during the survey, and levels generally exceeded the 5.0 mg l-1 criteria once into the month of September (Figure 22).

The available dissolved oxygen data suggest improving conditions over time in Mount Hope Bay. No anoxic conditions (<1.0 mg l-1) are noted in these data sets, which span nearly two decades, and hypoxic conditions are sporadic, not persistent over time, and are becoming less frequent in their occurrence. Summer (Jun–Sep) conditions clearly constitute worst case conditions in bottom waters, and often violate Class SA and SB dissolved oxygen criteria throughout the majority of the bay. However, the frequency of dissolved oxygen concentrations falling below 5.0 mg l-1 is decreasing over time, resulting in a reduction of the time that Mount Hope Bay waters do not meet water quality criteria.

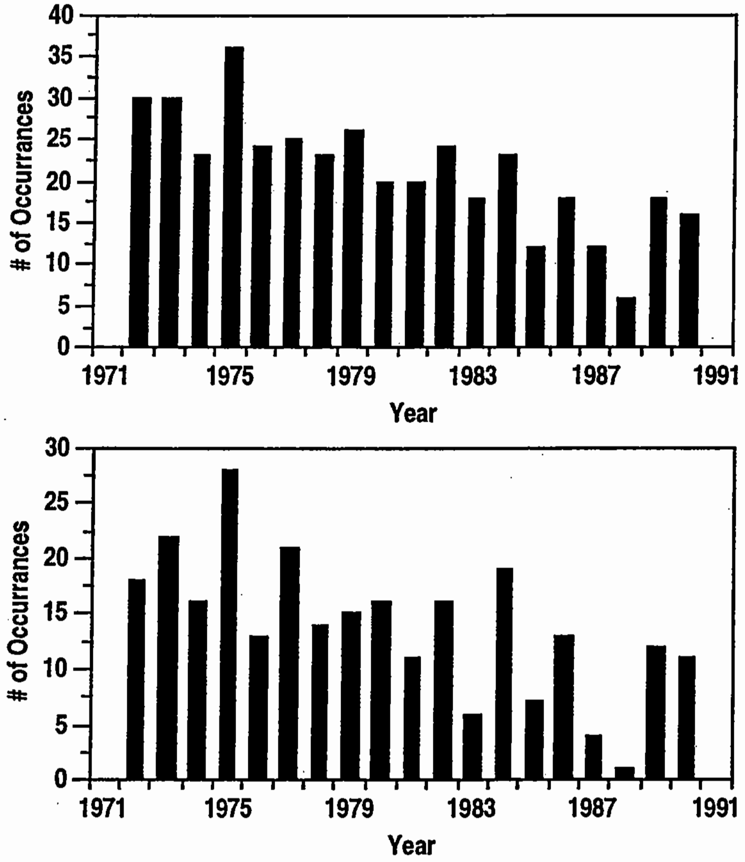


Figure 21. Frequency of occurance of saturation in bottom waters less than 80% (long—term averge) and 73% (August average) at the Spar Island station in Mount Hope Bay 1972–1990, showing a decrease in the frequency of both low saturation values. Data from MRI 1972–1990.

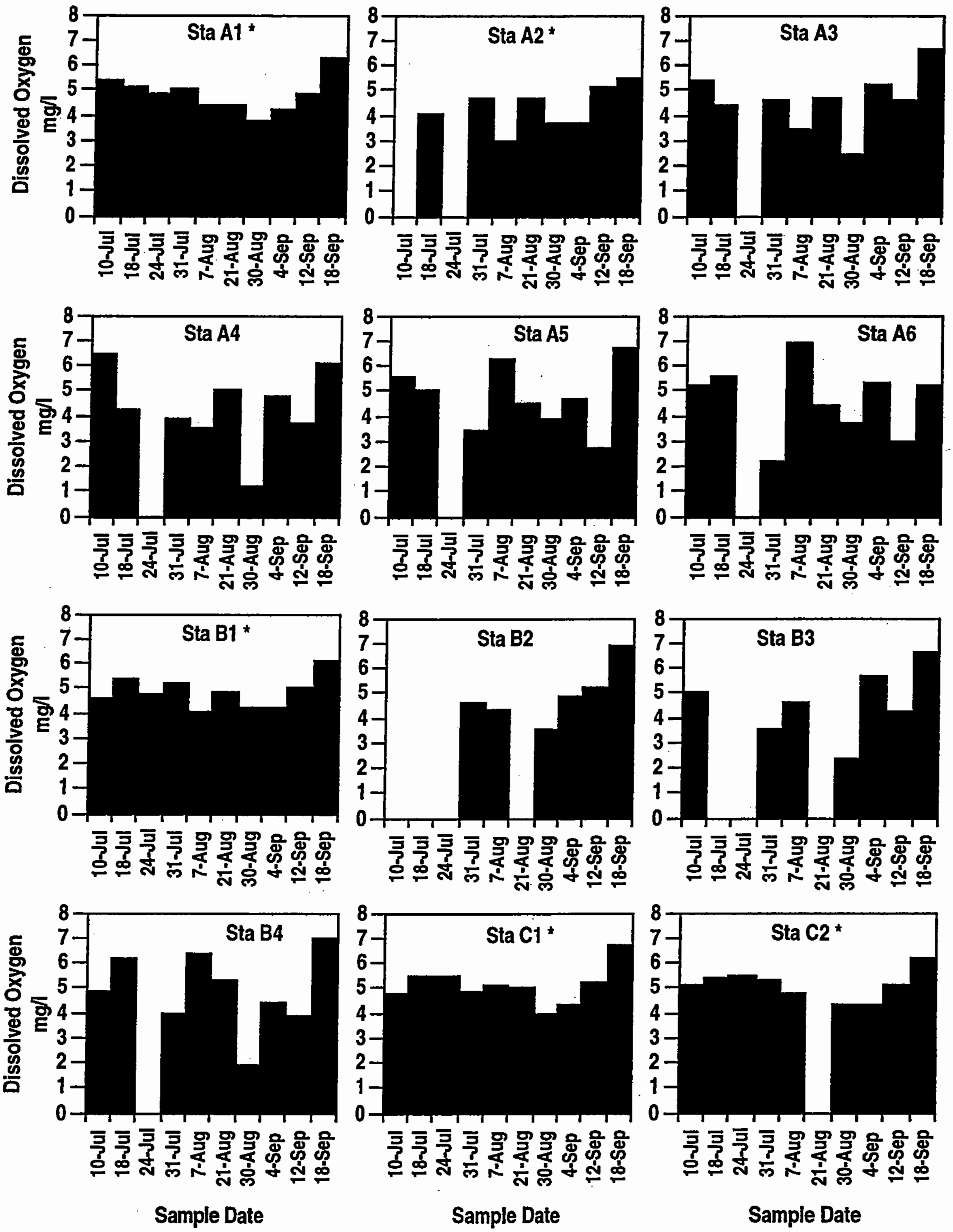


Figure 22 Pt1. Results of a dissolved oxygen study conducted by the Massachusetts Dept. of Environmental Protection during July, August, and September 1991. * indicates station in the dredged shipping channel. All oxygen measures are for bottom waters. Gaps represent missing data, not measures of zero oxygen content.

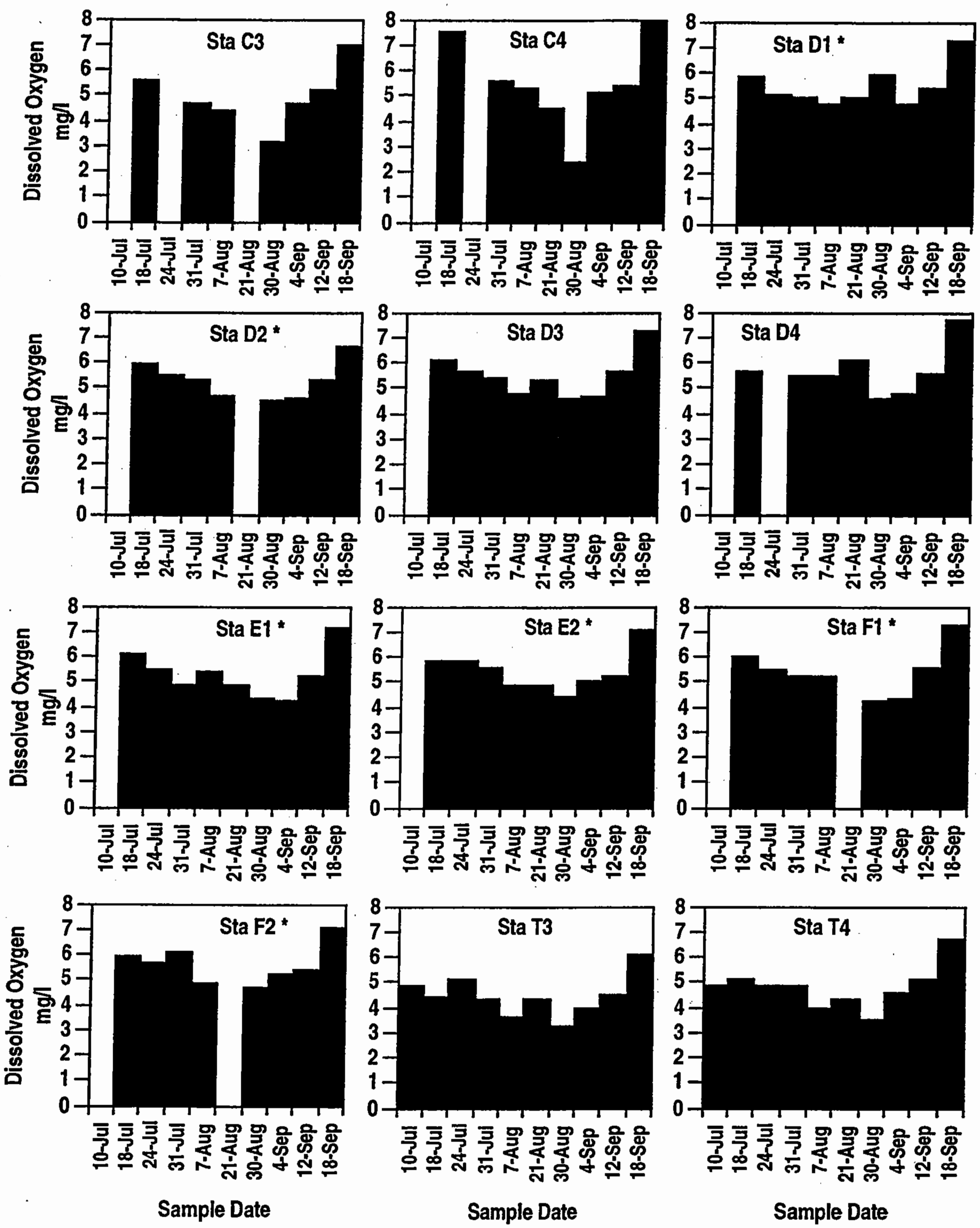


Figure 22 Pt2. Results of a dissolved oxygen study conducted by the Massachusetts Dept. of Environmental Protection during July, August, and September 1991. * indicates station in the dredged shipping channel. All oxygen measures are for bottom waters. Gaps represent missing data, not measures of zero oxygen content.

Despite the pattern of reduced low oxygen events in the bay, dissolved oxygen concentrations still fall below Class SA and SB water quality criteria on a regular basis throughout summer months. Evidently the pattern of observed dissolved oxygen conditions in the bay is not directly coupled to the BOD load directly discharged to the estuary by the Fall River STP, the estuaries largest point source discharge. Other factors, perhaps naturally occurring events, are effecting the dissolved oxygen concentrations in the bay over time. The dissolved oxygen data collected by Massachusetts DEP suggests that the area of worst dissolved oxygen conditions occurs within the western portion of Mount Hope Bay, north of the opening to the East Passage of Narragansett Bay. This could be the result of reduced circulation and flushing in that portion of the bay, as well as potentially being affected by the thermal effluent discharged from the Brayton Point Power Plant, which would be expected to have its greatest effect upon the western portion of Mount Hope Bay. The warm thermal effluent would reduce the quantity of dissolved oxygen able to be dissolved in the water, thereby reducing dissolved oxygen content. The thermal effluent from the facility is suspected to be the cause of the decrease in water temperatures in Mount Hope Bay, potentially as a result of an improved thermal effluent (Desbonnet and Lee 1991). The decreased frequency of low dissolved oxygen events in Mount Hope Bay, may be related to the decrease in water temperature in the bay. The relationship between the Brayton Point Power Plant discharge, water temperature trends in the bay, and dissolved oxygen concentrations should be further explored to determine if there is any cause and effect between these parameters.

Concentrations of dissolved oxygen in the western end of the bay are lower than those found in the dredged shipping channel in the bay (see Figure 22), as well as being generally worse than those regions of the bay closest to the sources of oxygen consuming effluent discharges (e.g., Fall River). If reduced flushing and circulation is the cause for the less favorable water quality in the western bay, this may also have some impact upon the conditions observed in the Lee, Cole, and Kickamuit Rivers.

Improvement of the CSO discharges to the estuary, as planned for Phase I and II of the Fall River CSO abatement program, will reduce the BOD load to Mount Hope Bay from the Fall River region. This in turn may also contribute to further reduction in the frequency of low dissolved oxygen events in the bay, and contribute to improved oxygen conditions in the bay overall, assuming that the low oxygen events are not naturally occurring. It is not known, however, if the reduction of BOD to the estuary from CSOs will improve oxygen conditions enough so that Class SB, and possibly Class SA, water quality criteria are met on a regular and consistent basis throughout the summer months. Considering the poor correspondence between BOD load from the Fall River STP, which is the estuaries largest source of BOD, and dissolved oxygen concentrations at Spar Island, it is improbable to plan for improved overall oxygen conditions in the bay as a result of CSO abatement measures, particularly if natural events, including flushing and circulation dynamics of the bay, are the cause of the observed low oxygen concentrations.

In smaller, less well flushed coves and embayments, BOD in runoff may be a significant factor in promoting degradation in some regions of the estuary, such as the Lee, Cole, and

Kickamuit Rivers. However, not enough information exists at present to adequately assess the potential impact of BOD from runoff and other sources upon these smaller coves and bays attached to Mount Hope Bay.

In summary, low dissolved oxygen measures in bottom waters, which violate Class SA and SB criteria in both states, are common events during summer months. The cause of the low oxygen bottom waters is not known, nor are the impacts, if any, upon benthic organisms. Conditions, however, appear to be improving over time, although the cause of the improvement is not clear.

The states of Rhode Island and Massachusetts, through the Interstate Committee, should seek funding to implement a study of dissolved oxygen throughout the estuary to determine if the observed low oxygen events are of natural or anthropogenic origin, as well as to assess potential impacts upon benthic flora and fauna. Once funding is found, the study could be completed by cooperative agreement between state agencies, or contracted outside of the state agencies to academic researchers or an environmental consulting firm. The goal of the study should be to assess the origin of low oxygen bottom waters, and to determine sources if found to be of anthropogenic origin, as well as defining potential improvement if identified sources are abated. Further suggestion for study of dissolved oxygen concentrations are noted and detailed in CCMP Section 04–01–02 III. C. Source Reduction: Nutrients, which should be reviewed by the state agencies and incorporated accordingly.

The Interstate Committee should use the results of this study to plan for the abatement of contaminant sources, if any, or to re–define water quality descriptions to account for the natural occurance of low oxygen bottom waters in the estuary.

Furthermore, Marine Research Inc., as part of its duties in monitoring the quality of the effluent and recieving waters affected by the Brayton Point facility, should be required to compile, computerize, and analyze the data pertaining to its effluent discharge and recieving water conditions. The specific parameters that MRI should test are: for the effect of the thermal effluent on water temperatures of the bay; long–term changes in the temperature of the effluent; if the changes in the effluent could account for the observed decrease in Mount Hope Bay water temperatures; if the thermal effluent is effecting the flushing and circulation dynamics of the bay; and/or if the effluent effects the quantity of dissolved oxygen contained in the water column, particularly during summer months. The results of these analyses should be used by the Interstate Committee to determine if changes in the discharge criteria of the thermal effluent of the Brayton Point facility would serve to improve oxygen conditions in the western portion of Mount Hope Bay. This would be only one component of that recommended through CCMP Section 05–02–04 Long–Term Monitoring for the analysis of data through revision of the Brayton Point NPDES permit review process.

IV. Metals and Toxics in the Mount Hope Bay Estuary

Metals in marine environments are typically referred to as trace elements. They are found dissolved in seawater at low concentrations, and are required in only very small quantities to maintain the proper growth and metabolism of marine plants and animals. Metals are problematic when they become over–abundant in the environment, to the point where plants and animals accumulate metals in excess of required concentrations in their tissues. These metals are then passed along the food chain to higher trophic levels, where concentrations of accumulated metals in body tissues may become great enough that biological functions are impaired (i.e., reproduction). Excess metals can also become toxic to the host organism, and cause disease and/or death. Metals often accumulate in body tissues to a point where they are not toxic to the host organism, but present a long—term health risk to persons consuming the contaminated tissues.

Once metals enter the coastal environment, some are incorporated by organisms for growth, or simply accumulate in body tissues. Those metals not incorporated into the biota, if they are not removed from the environment through physical processes, are generally retained in bottom sediments to which they adsorb. The metals can often accumulate at high concentrations in sediments and pose long—term problems from sediment re-suspension into the water column, intake by benthic deposit feeders, and risks associated with dredging activities and dredge spoil disposal.

Metal concentrations in the Mount Hope Bay estuary water column generally do not exceed EPA criteria for aquatic life on either long-term or short-term time frames and are not at present limiting the human use of Mount Hope Bay. However, the long—term effect of metal and toxics accumulations in bottom sediments on benthic flora and fauna is poorly understood. EPA is in the process of developing criteria and guidance for metals concentrations in marine sediments, and once adopted, will better define the potential impact of metals in marine sediments upon resident and visiting marine life.

Metals Loadings

Seventy–three percent of the copper entering the estuary is derived from Narragansett Bay and the Sakonnet River (Table 5). The next largest sources are urban runoff and the Taunton River, both contributing 9% of the total copper load to the estuary. STPs contribute 6%, industry 2%, and the atmosphere 1% of copper loading to the estuary. Of controllable sources of copper to the estuary, the Taunton River and runoff provide the greatest proportion (34% and 35%, respectively), closely followed by STPs (24%; Figure 23). Industry provides 7% of the controllable copper load.

Narragansett Bay and the Sakonnet Rivers are the major providers of chromium to the estuary, providing 61% of the total loading (Table 6). STPs (Fall River STP only) provide the second largest source of chromium to the estuary (27%), and the largest controllable source (68%; Figure 24). The Taunton River provides the second largest controllable sourceof

Table 5. Total copper loading to the Mount Hope Bay estuary in kilograms per year, and percentage of total and controllable loadings.

Source	Loading By Source	Total Loadings	Percent of Total Loading	Percent of Controllable Loading[1]
STPs[2]		**1536**	**6**	**24**
Somerset STP	na			
Taunton STP	na			
Fall River STP	1536			
CSOs		**na**		
Industry[2]		**411**	**2**	**7**
Taunton River[3]		**2172**	**9**	**34**
Runoff[4]		**2244**	**9**	**35**
Sub-Taunton Runoff	1771			
Sub-Mt. Hope Runoff	473			
ISDS		**na**		
Boats		**na**		
Marine Sources[5]		**17363**	**73**	
East Passage	13224			
Sakonnet River	4139			
Atmosphere[6]		**72**	**1**	
TOTAL LOADING		**23798**		

[1] Percent of controllable loading refers to all sources except for the atmosphere and marine sources.

[2] From NPDES records; EPA Region I (1990).

[3] Estimated from concentration and flow data in Pilson and Hunt (1989).

[4] Estimated from Schueler (1987); RIGIS (1992); MAGIS (1992); see Appendix __ for cencentration data sources used in the loadings model.

[5] Estimated from modeled flow according to salt mass balance; see Appendix __ for details.

[6] Estimated according to deposition rates in Nixon and Pilson (1984) and water surface area (RIGIS 1992; MAGIS 1992).

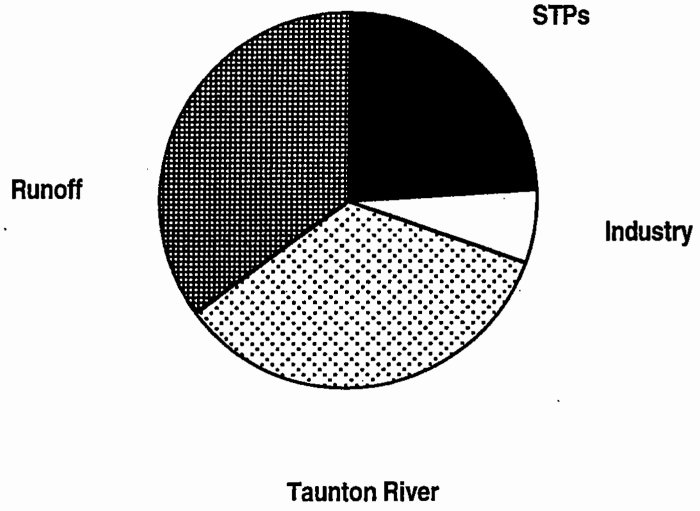


Figure 23. Contribution of copper to the Mount Hope Bay estuary from controllable sources.

chromium (30%). Industry and the atmosphere each account for 1% or less of the total chromium load to the estuary, while industry provides 2% of the total controllable chromium load to the estuary.

Table 6. Total chromium loading to the Mount Hope Bay estuary in kilograms per year, and percentage of total and controllable loadings

Source	Loading By Source	Total Loadings	Percent of Total Loading	Percent of Controllable Loading[1]
STPs[2]		1744	27	68
Somerset STP	na			
Taunton STP	na			
Fall River STP	1744			
CSOs		na		
Industry[2]		50	1	2
Taunton River[3]		763	12	30
Runoff		na		
Sub-Taunton Runoff				
Sub-Mt. Hope Runoff				
ISDS		na		
Boats		na		
Marine Sources[4]		3876	61	
East Passage	2890			
Sakonnet River	986			
Atmosphere[5]		16	<1	
TOTAL LOADING		6449		

[1] Percent of controllable loading refers to all sources except for the atmosphere and marine sources.

[2] From NPDES records; EPA Region I (1990).

[3] Estimated from concentration and flow data in Pilson and Hunt (1989).

[4] Estimated from modeled flow according to salt mass balance; see Appendix __ for details.

[5] Estimated according to deposition rates in Nixon and Pilson (1984) and water surface area (RIGIS 1992; MAGIS 1992).

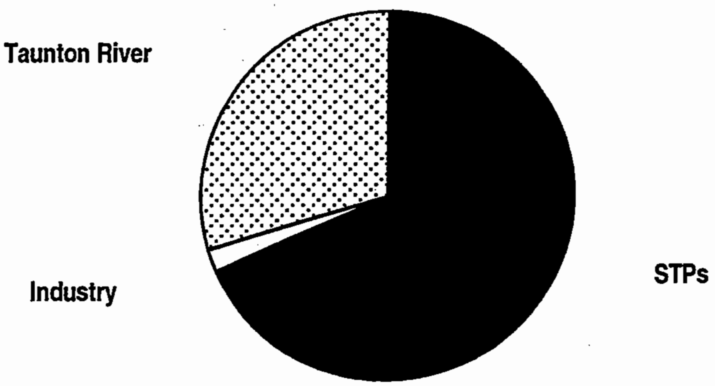


Figure 24. Contribution of chromium to the Mount Hope Bay estuary from controllable inputs.

Of those sources assessed, Narragansett Bay and the Sakonnet River provide the largest contribution of cadmium to the estuary (50%; Table 7). The Taunton River, STPs, and runoff to the estuary provide 17%, 17%, and 16% of the total cadmium load to the estuary, respectively. These three sources represent equal contributions of controllable input of cadmium to the estuary (Figure 25). Industry provides less than 1% of the total and controllable cadmium load.

Urban runoff provides that greatest proportion of lead to the estuary, accounting for 60% of the total load (Table 8). Narragansett Bay and the Sakonnet River provide 12% of the total lead load to the estuary, while CSOs contribute 10% of the total. STPs (7%), the Taunton River (6%), and the atmosphere (5%), provide lesser, but nearly equal loadings of lead to the estuary. Urban runoff comprises 74% of controllable lead input to the estuary, followed by CSOs (11%), STPs (8%), and the Taunton River (7%; Figure 26). Industry provides less than 1% of both the total and controllable lead loading to the estuary.

Narragansett Bay and the Sakonnet River provide 89% of the total load of nickel to the estuary of those sources assessed (Table 9). The Taunton River is the second largest source, contributing 10% of the total nickel load. Industry and the atmosphere both contribute 1% or less of the total load of nickel to the estuary, and STPs provide 3% of the total. Nickel input from

Table 7. Total cadmium loading to the Mount Hope Bay estuary in kilograms per year, and percentage of total and controllable loadings.

Source	Loading By Source	Total Loadings	Percent of Total Loading	Percent of Controllable Loading[1]
STPs[2]		**274**	**17**	**34**
Somerset STP	na			
Taunton STP	na			
Fall River STP	274			
CSOs		**na**		
Industry[3]		**2**	**<1**	**<1**
Taunton River[2]		**269**	**17**	**33**
Runoff[4]		**262**	**16**	**33**
Sub-Taunton Runoff	207			
Sub-Mt. Hope Runoff	55			
ISDS		**na**		
Boats		**na**		
Marine Sources[5]		**809**	**50**	
East Passage	612			
Sakonnet River	197			
Atmosphere		**na**		
TOTAL LOADING		**1616**		

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[1] Percent of controllable loading refers to all sources except for the atmosphere and marine sources.

[2] Estimated from concentration and flow data in Pilson and Hunt (1989).

[3] From NPDES records; EPA Region I (1990).

[4] Estimated from Schueler (1987); RIGIS (1992); MAGIS (1992); see Appendix __ for cencentration data sources used in the loadings model.

[5] Estimated from modeled flow according to salt mass balance; see Appendix __ for details.

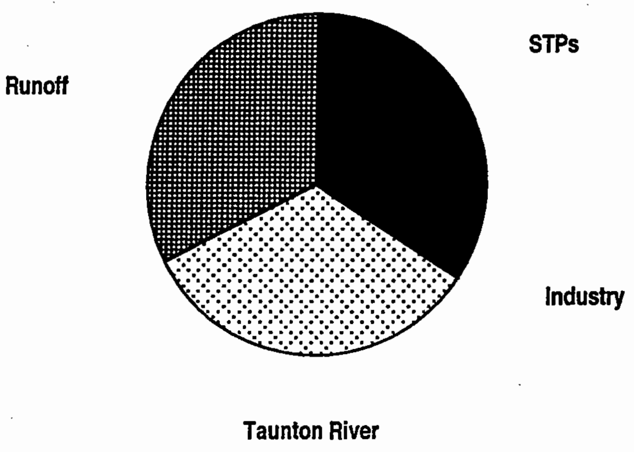

Figure 25. Contribution of cadmium to the Mount Hope Bay estuary from controllable sources.

Table 8. Total lead loading to the Mount Hope Bay estuary in kilograms per year, and percentage of total and controllable loadings.

Source	Loading By Source	Total Loadings	Percent of Total Loading	Percent of Controllable Loading[1]
STPs[2]		1052	7	8
Somerset STP	na			
Taunton STP	na			
Fall River STP	1052			
CSOs[3]		1428	10	11
Industry[4]		4	<1	<1
Taunton River[2]		898	6	7
Runoff[5]		9188	60	74
Sub-Taunton Runoff	7254			
Sub-Mt. Hope Runoff	1934			
ISDS		na		
Boats		na		
Marine Sources[6]		1730	12	
East Passage	1139			
Sakonnet River	591			
Atmosphere[7]		725	5	
TOTAL LOADING		15025		

[1] Percent of controllable loading refers to all sources except for the atmosphere and marine sources.

[2] Estimated from concentration and flow data in Pilson and Hunt (1989).

[3] Estimated from concentration data in Novotny (1991) and flow from Maguire Group (1987).

[4] From NPDES records; EPA Region I (1990).

[5] Estimated from Schueler (1987); RIGIS (1992); MAGIS (1992); see Appendix __ for concentration data sources used in the loadings model.

[6] Estimated from modeled flow according to salt mass balance; see Appendix __ for details.

[7] Estimated according to deposition rates in Nixon and Pilson (1984) and water surface are (RIGIS 1992; MAGIS 1992).

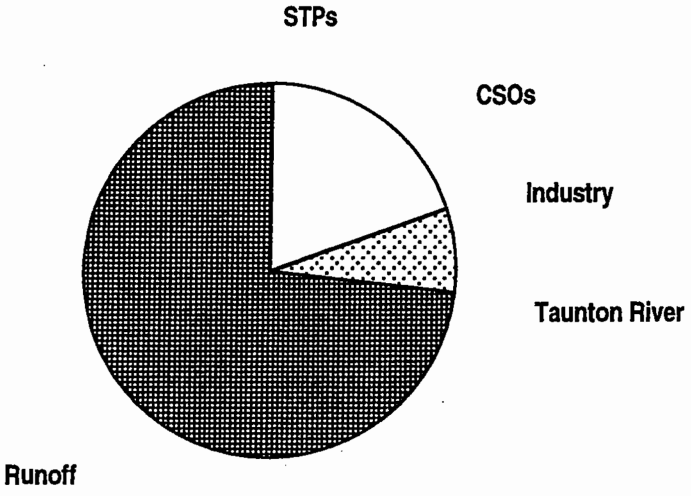

Figure 26. Contribution of lead to the Mount Hiope Bay estuary from controllable inputs.

Table 9. Total nickel loading to the Mount Hope Bay estuary in kilograms per year, and percentage of total and controllable loadings.

Source	Loading By Source	Total Loadings	Percent of Total Loading	Percent of Controllable Loading[1]
STPs[2]		**930**	**3**	**19**
Somerset STP	na			
Taunton STP	na			
Fall River STP	930			
CSOs		**na**		
Industry[3]		**291**	**1**	**6**
Taunton River[2]		**3580**	**10**	**75**
Runoff		**na**		
Sub-Taunton Runoff				
Sub-Mt. Hope Runoff				
ISDS		**na**		
Boats		**na**		
Marine Sources[4]		**30634**	**86**	
East Passage	22093			
Sakonnet River	8541			
Atmosphere[5]		**126**	**<1**	
TOTAL LOADING		35561		

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[1] Percent of controllable loading refers to all sources except for the atmosphere and marine sources.
[2] Estimated from concentration and flow data in Pilson and Hunt (1989).
[3] From NPDES records; EPA Region I (1990).
[4] Estimated from modeled flow according to salt mass balance; see Appendix __ for details.
[5] Estimated according to deposition rates in Nixon and Pilson (1984) and water surface are (RIGIS 1992; MAGIS 1992).

the Taunton River comprises 75% of the controllable nickel loading (Figure 27). STPs make up 19% of controllable nickel input to the estuary, and industry makes up 6% on controllable nickel input.

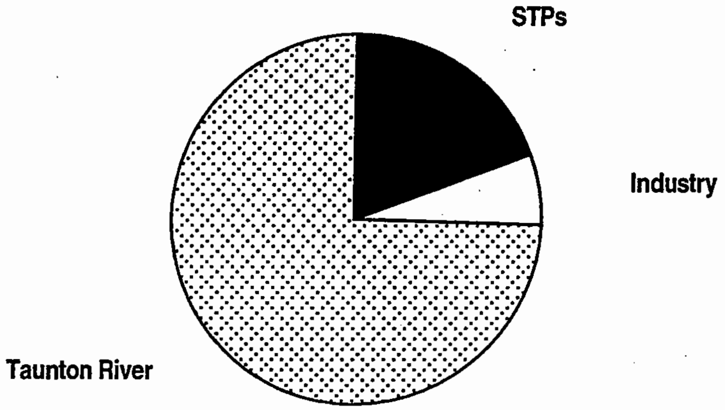


Figure 27. Contribution of nickel to the Mount Hope Bay estuary from controllable sources.

Only three sources had data available for which an assessment of zinc loading to the estuary could be made. STPs (Fall River STP only) were the largest contributor of zinc, providing 66% of the total and controllable sources (Table 10; Figure 28). Urban runoff was the other major source of zinc to the estuary, providing 34% of total and controllable loading of this metal. Industry provided less than 1% of the total and controllable zinc entering the estuary.

Patterns of discharge of metals from the Fall River STP, the largest direct discharge to the estuary, is shown in Figure 29. The discharge of copper and chromium have remained relatively constant over the time span of 1983 to 1990. Discharges of zinc, however, have been increasing in the effluent of the plant since 1983. The loading of zinc to the estuary from the STP very closely follows the pattern of increased flow over time, and also over its seasonal pattern. This suggests that overall concentrations of zinc may not be increasing, but that zinc is not effectively removed during the settling process, and loading increases as effluent flow increases.

Concentrations of metals in sediments of the estuary generally decrease down estuary, but experience increased concentrations in the region south of Spar Island, except for chromium, which shows no increase in that area of the bay (US ACOE 1982; Table 11; Map 3). The reason for this pattern is unclear, but may be a result of shipping activity, or local historical discharge or dumping. Concentrations of nickel, lead, and cadmium are greater in this region of Mount Hope Bay than in the region approximately one-mile north of the Braga Bridge. One potential cause may be the proximity of oil and gas transfer depots to the region of these high sediment concentrations.

Table 10. Total zinc loading to the Mount Hope Bay estuary in kilograms per year, and percentage of total and controllable loadings.

Source	Loading By Source	Total Loadings	Percent of Total Loading	Percent of Controllable Loading[1]
STPs[2]		20472	66	66
Somerset STP	na			
Taunton STP	na			
Fall River STP	20472			
CSOs		na		
Industry[2]		150	<1	<1
Taunton River		na		
Runoff[3]		10501	34	34
Sub-Taunton Runoff	8291			
Sub-Mt. Hope Runoff	2210			
ISDS		na		
Boats		na		
Marine Sources		na		
East Passage				
Sakonnet River				
Atmosphere		na		
TOTAL LOADING		31123		

[1] Percent of controllable loading refers to all sources except for the atmosphere and marine sources.

[2] From NPDES records; EPA Region I (1990).

[3] Estimated from Schueler (1987); RIGIS (1992); MAGIS (1992); see Appendix __ for concentration data sources used in the loadings model.

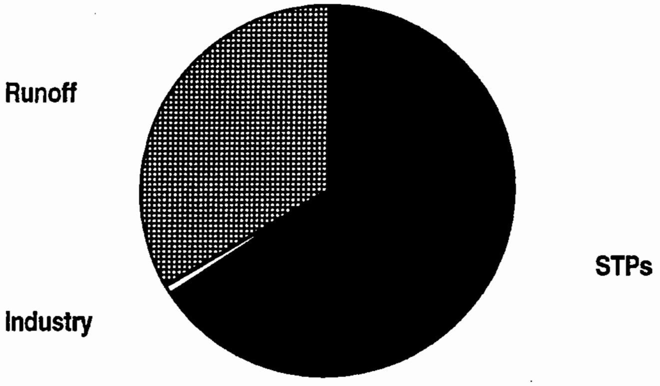


Figure 28. Contribution of zinc to the Mount Hope Bay estuary from controllable sources.

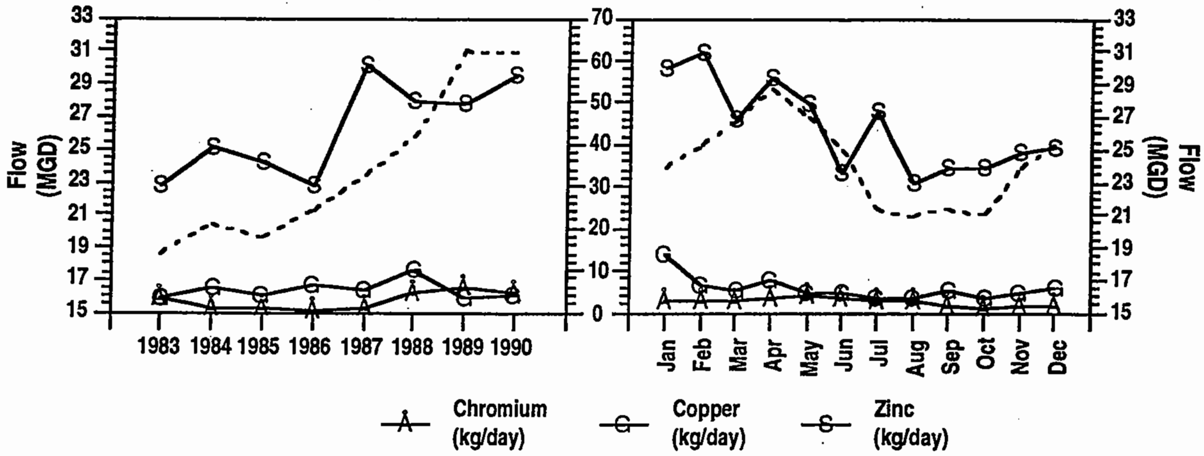
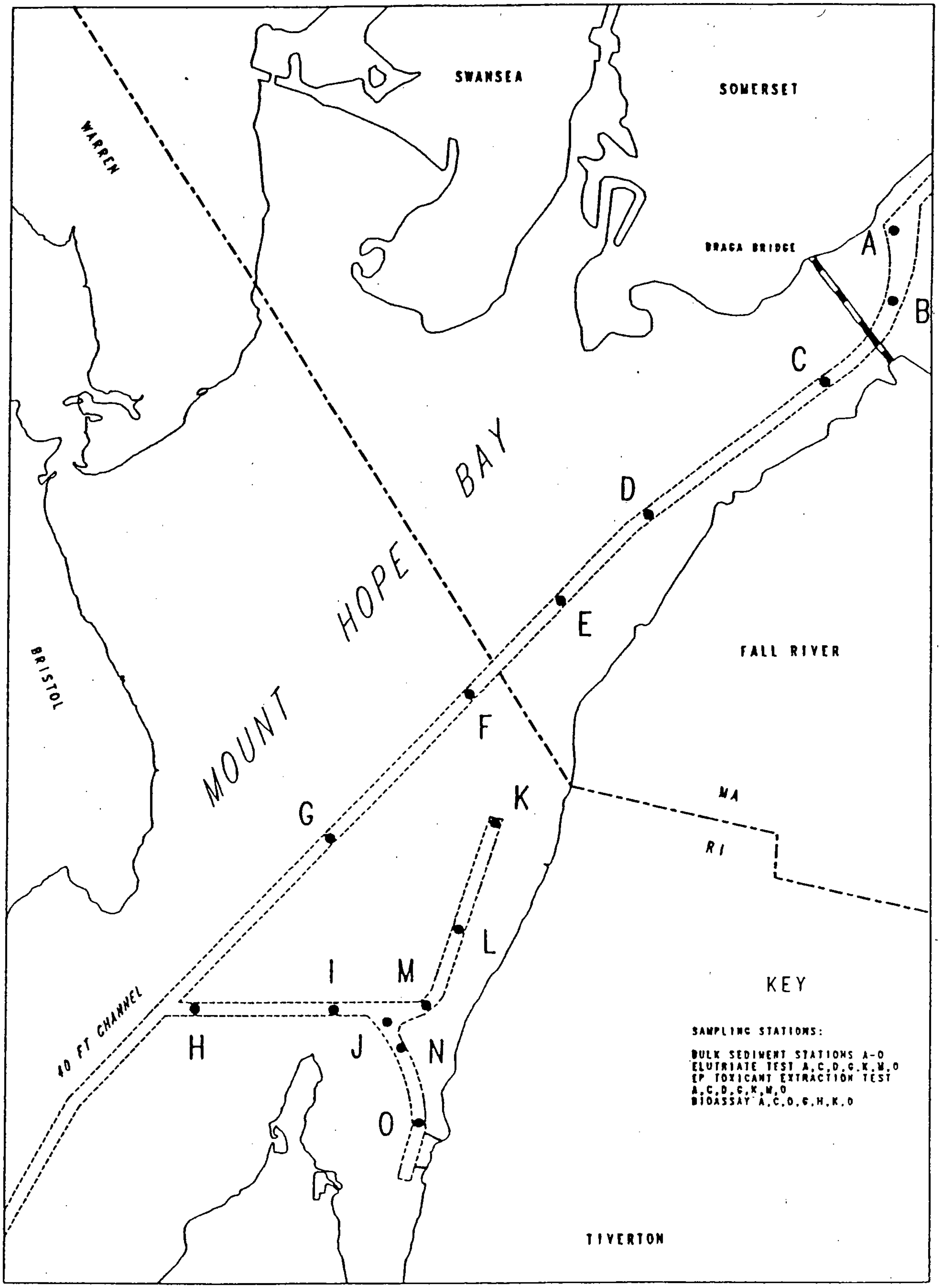


Figure 29. Average annual and seasonal patterns of loading for copper, chromium, and zinc from the Fall River STP 1983-1990. Flow is plotted for comparative purposes. Only zinc shows a strong long-term trend, which appears related to flow. Chromium shows a slight increase since 1986, while copper loading has remained mostly unchanged. Data from NPDES Permit Records, EPA Region 1.

Table 11. Concentrations of metals in bulk sediments from the tidal Taunton River and Fall River Harbor (see Map 3 for station locations). Data are from US ACOE (1982) and given in ppm.

Station	Concentration					
	Hg	Cd	Cu	Ni	Pb	Cr
A	3.2	2	38	45	47	163
B	3.1	2	52	44	56	315
C	2.0	2	32	33	42	137
D	2.3	1	38	43	38	165
E	1.2	6	20	61	26	57
F	0.8	6	19	55	16	49
G	0.4	<1	20	49	56	57
H	1.2	6	30	76	42	44
I	0.2	<1	6	32	23	13
J	7.3	8	42	60	39	93
K	1.3	2	30	59	32	34
L	0.7	8	17	28	24	23
M	1.6	<1	43	27	50	112
N	1.4	12	42	24	36	42
O	1.4	<1	34	38	55	108



Map 3. Sampling locations for nutrients.

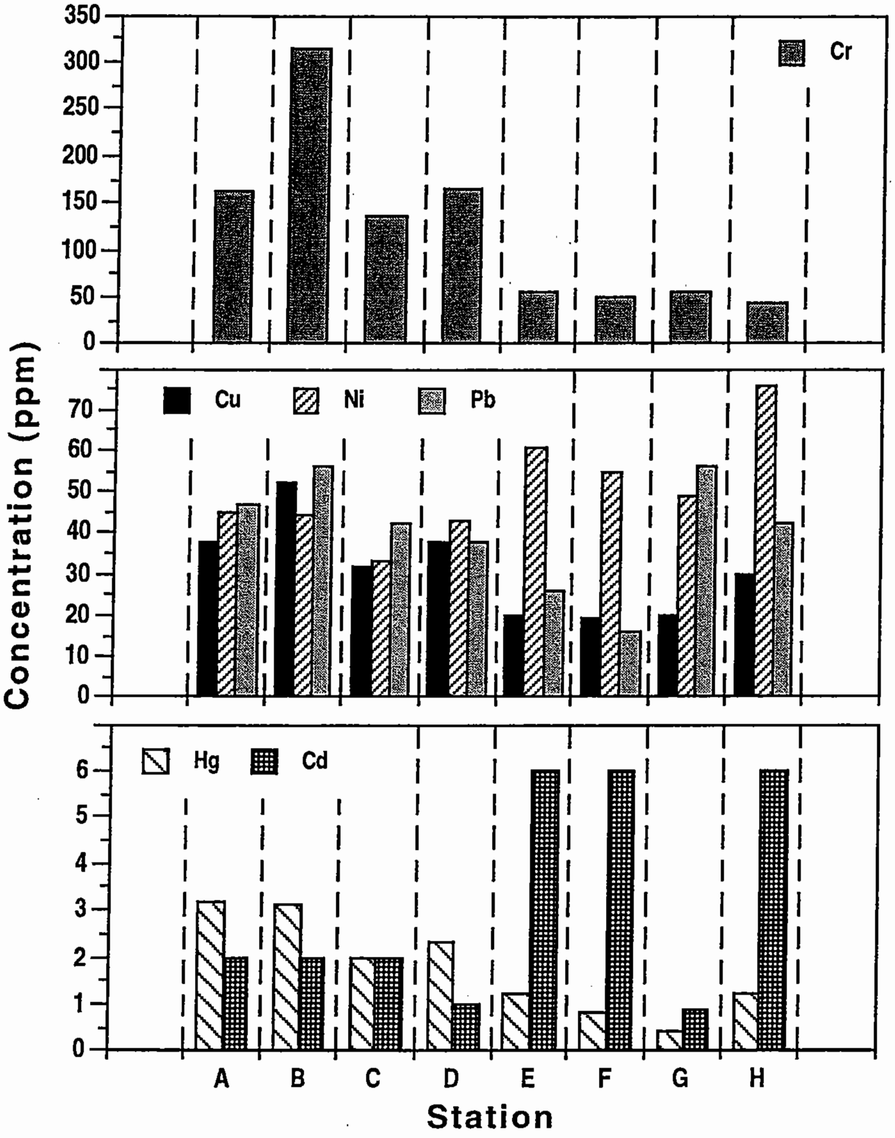


Figure 30. Down estuary transect of metals concentrations in bulk sediment samples from the tidal Taunton River and Mount Hope Bay. Data from USACOE (1982) as given in Table 11.

One metal that has been of concern with regard to use of the bay as a shellfishing resource is the abundance of mercury in hard clam (Mercenaria mercenaria) tissues. Concern over mercury concentrations in the tissues of Mount Hope Bay hard clams originates from the discharge of mercury in effluent by ICI Americas, an industry in Dighton, MA. However, mercury has not been discharged since 1974 (Pratt 1988) and 1985–86 samples of hard clam tissues from Mount Hope Bay did not exceed levels considered acceptable for shellfish consumption (Thibault/Bubley 1987). It is presumed that concentrations of mercury in shellfish tissues will continue to decline over time as mercury discharges directly to the bay are reduced. Army Corps of Engineers sediment surveys in 1976 and 1982 found higher

Table 12. Concentrations of metals in quahaug tissues taken from the tidal Taunton River and Mount Hope Bay during October 1989 (see Map 2; (p. 3) for station locations). Data are from Marine Research Inc. (1990) and given in µg/g. Rhode Island Health Dept. Alert Levels are given for comparative purposes.

Metal	**Concentration**						
	RB N	Assonet River	Montaup	Lee River	Brayton Point	Spar Island	RI Alert Criteria
Cadmium	1.60	0.49	0.38	<0.22	0.28	<0.26	0.5
Chromium	10.0	3.60	2.40	<1.0	3.40	1.70	1.0
Copper	120	25.0	8.30	2.60	3.80	5.70	10.0
Lead	14.0	1.40	2.40	0.86	0.34	1.40	4.0
Nickel	21.0	13.0	16.0	3.40	8.50	7.40	na
Zinc	440	240	140	110	54.0	86.0	65.0

concentrations of mercury in sediments from the tidal Taunton River than from Mount Hope Bay, as well as a gradual decrease along a down estuary transect, suggesting that the major source was in the Taunton River, probably ICI Americas Inc. in Dighton, MA. High concentrations of merucry in the sediments, however, if resuspended to the water column, may cause long—term concern for concentrations in hard clam meats since these filter feeders will continually take resuspended mercury from the water column. This may be most important during dredging operations, when many contaminants contained in bottom sediments are resuspended and become available for uptake by benthic fauna.

Long—term studies of metals in hard clam tissues undertaken by MRI between 1979 and 1989 show two general trends: increased concentrations of metals between 1979 and 1985; decreased concentrations between 1985 and 1989 (MRI 1990). Concentrations of several metals as recorded in October 1989 samples show that several stations exhibit metals concentrations that exceed Rhode Island Dept. of Health Alert Levels (Table 12). Alert levels are used to bring attention to those samples that exceed the criteria, but do not denote "problematic" concentrations per se, but that they should recieve further observation to determine what is causing the increased levels of metals, and if the observed increases are persistent or due only to some episodic event. Some concern over concentrations of chromium and zinc is suggested by the higher concentrations observed at a number of sample stations. These data also show a decreasing trend with distance down estuary for all sampled metals, and suggests that the source of the metals are generally in or above the tidal portion of the Taunton River (MRI 1990).

Metals concentrations from water column samples taken by Pilson and Hunt (1989) during the fall of 1985 and the spring of 1986 show that metals concentrations did not exceed the EPA chronic criteria at either station in Mount Hope Bay (Table 13). The EPA chronic criteria for copper was, however, exceeded in the tidal portion of the Taunton River during the spring of 1986, and chronic criteria for nickel was exceeded during the Fall of 1985 (Table 13).

Table 13. Concentrations of dissolved metals in surface waters in the tidal Taunton River, and two stations in Mount Hope Bay. Data are from Pilson and Hunt (1989), and are averages for the Fall of 1985 (Oct/Nov) and for Spring 1986 (Apr/May), and given in µg l-1. EPA chronic criteria are given for comparative purposes.

Metal		**Location**		**EPA Criteria**
	Station 17	Station 18	Taunton River	
Copper				2.9
Fall 85	1.29	1.22	2.49	
Spring 86	1.11	0.90	3.47	
Cadmium				9.3
Fall 85	0.44	0.46	0.75	
Spring 86	0.42	0.42	0.11	
Chromium				5.0
Fall 85	0.24	0.22	na	
Spring 86	0.19	0.19	0.64	
Nickel				8.3
Fall 85	2.61	2.47	9.66	
Spring 86	1.35	1.47	2.31	
Lead				5.6
Fall 85	0.15	0.97	na	
Spring 86	0.10	0.07	0.94	

Loadings of metals have generally declined throughout the region from STPs and industry alike since the early to mid-1980s (Desbonnet and Lee 1991). However, loading of zinc from the Fall River STP has increased by approximately 1 kg per day between 1983 and 1990. The trend for increased zinc loading is mirrored in upper Narragansett Bay municipal discharges (Desbonnet and Lee 1991), but the cause is not readily apparent and requires further study, especially since zinc loading has increased over time and has exceeded RI Alert Levels in recent years. MRI (1990) also noted that zinc has shown an increasing trend in clam tissue concentrations between 1979 and 1989. Other than this, the general trend for those metals investigated is towards reduced or stable loading to the bay or in clam meats.

The occassional measure of metal concentrations that exceed EPA chronic criteria suggests that metals may, on occassion, be problematic in at least the tidal Taunton River. This would also suggest that sources that provide metals to the tidal portion of the Taunton River are often times potent, and may carry greater impact upon the area of origin than that which is expressed in the estuary.

Accumulated metals in bottom sediments, however, will pose the greatest long—term concern with regard to effects upon living resources of the estuary and for dredge spoil disposal options. Dredging operations in the estuary will resuspend metals and toxics accumulated in bottom sediments of the estuary, making them available for biological uptake and entrance into the estuarine food web once again. Furthermore, there are at present no criteria by which to assess the potential impact of metals and toxics concentrations in marine sediments, and therefore no clear definition if metals are indeed problematic to benthic dwelling organisms over the long– or short–term.

The real concern over metals concentrations in bottom sediments will arise when dredging plans are prepared for areas of the Mount Hope Bay estuary. Concentrations of heavy metals contained in the dredge spoils will determine how and where they can be disposed. This is a concern that will need to be addressed in the near future, as previously dredged channels have not been dredged since at least the early 1970s, and are now filling in to the point where maintenance dredging is required to ensure their continued use as navigation and shipping channels.

The Taunton River as a source of metals to the estuary is similar in its magnitude to that from runoff or STPs. Measurements of metals, and other water quality parameters used in this assessment, however, are taken in the tidal portion of the river, and may be an under estimate of true concentrations contained in the river water due to mixing and dilution. In order to gain a better estimate of loading from the Taunton River, a more detailed survey of water quality parameters would need to be conducted above the head of tide. It is likely that nonpoint runoff is a major supplier of metals to the Taunton River, considering the size and urban nature of the watershed. In order to gain a better understanding of pollutant and nutrient loading to the non–tidal Taunton River, a detailed assessment, by subwatershed region, would need to be undertaken in the Taunton river watershed, combined with ambient water quality studies.

Urban runoff directly to the estuary is calculated to be a source of all metals that equals the input of both the Taunton River and STPs. Again, to establish the magnitude and potential impact of this source, field studies would be required on a subwatershed basis, and combined with ambient water quality sampling routines. Sewage treatment plants are sources of metals to the estuary, along with the Taunton River and runoff, particularly for zinc. Municipal treatment facilities that receive wastewater from industry should ensure adequate pretreatment of industrial wastes prior to their discharge into the municipal treatment system. Sewage treatment plants are not designed to reduce metals from their effluent other than those metals that are removed as a particulates precipitated to sludge during the settling process. Poorly treated industrial input to the municipal system will result in elevated concentrations in the STP discharge effluent, increased loading the to estuary, and elevated concentrations of toxics in sewage sludge, which could present disposal problems. Industrial wastewater pretreatment programs must be adequate in order to abate metals discharges from STPs.

In summary, metals are generally not problematic within the Mount Hope Bay estuary water column, and only occassional samples have been noted to exceed EPA Chronic Criteria, and then only in the tidal portion of the Taunton River. Sampling, however, is very sporadic over time, and not very extensive throughout the estuary, limiting the value of this observation. Similarly, metals concentrations in hard clam tissues are generally within acceptable risk limits with regard to human consumption, and only chromium and zinc have exceeded Rhode Island Dept. of Health Alert Levels, signifying that they should be observed more carefully with regard to future trends and changes in their concentration levels.

The metals chromium and zinc are therefore of concern, and merit further study to determine more clearly the individual input sources of these metals. Zinc loading from the Fall River STP has clearly increased in recent times, and chromium loading shows some increase since 1987. The Fall River STP is the major contributor of chromium (68%) and zinc (66%) to the estuarine system, and should recieve greater study with regard to these two priority metals. The studies should be performed by the state of Massachusetts Dept. of Environmental Protection and Fall River STP personnel, and should attempt to identify the sources of chromium and zinc to the Fall River STP facility, as well as identifying ways to reduce both input to the facility and output from the facility to the estuary. The ultimate goal of MADEP and the Fall River STP staff should be to reduce the loading of zinc and chromium from the facility, with an interum goal of not increasing present levels of loadings of these, as well as other metals, to the estuary. Further recommendations for the reduction of toxic metals input to the estuary are given in CCMP Section 04–01–01 Source Reduction: Toxics, and should be reviewed by respective state agencies, as well as the Interstate Committee, to determine the implementation of these source control measures.

However, higher concentrations of both metals in samples taken up estuary suggest more potent sources in the tidal Taunton River or possibly in the freshwater section of the river. Clearly, further study is required in the Taunton River and its tidewater to determine these potentially more potent sources of metals to the estuary. This study should be accomplished by the MADEP, with the express intent of the identification of sources, followed by actions to reduce metals input to the estuary once the sources are located and identified. Chromium and zinc should be considered priority metals for further study, although other metals and their sources should not be ignored as time and funding permits. Further recommendations for the study of toxics in the estuary are given in CCMP Sections 05–02–04 Long–Term Monitoring and 04–02–03 Public Health.

Metals are present in the sediments of the Mount Hope Bay estuary in concentrations generally expressed in decreasing levels with distance from the head of the estuary, except within the region of the petroleum transfer facilities just south of the city of Fall River which show elevated metals concentrations. Although sediment concentrations could not be assessed due to lack of criteria, metals in sediments will need to be addressed in the near future as dredging plans are developed for the channels and ports within the estuary.

The states of Rhode Island and Massachusetts should begin to jointly develop a dredging strategy for the estuary through the Interstate Committee and the US ACOE. The strategy for dredging should: prioritize those areas that most critically require dredging to remain viable as transport corridors through the estuary; where the areas of highest metals and toxics contamination exist within the estuary; the volume and quality of sediments to be removed; disposal options based upon the volume and quality of the dredged spoils; and the potential impacts upon resident and migratory fishes and invertebrates based upon the volume and quality of the sediments, and the timing or season that the proposed dredging will take place.

Once the dredging strategy is completed by the states, a schedule of dredging activities for the estuary should be developed in cooperation with the US ACOE, adequate funding sought and obtained, and dredging operations undertaken according the prioritized plan to keep the estuary open as a viable shipping and transport avenue. CCMP Section 04–03–04 Management of Marine and Riverine Sediments, I [Dredging Activities]; should be reviewed and implemented by respective state agencies, the Interstate Committee, and USACOE for implementation and consideration.

Nutrients in the Mount Hope Bay Estuary

Nutrients are considered pollutants when they cause excessive growth of aquatic plants, such as phytoplankton or seaweeds. Nitrogen is typically the nutrient of concern in coastal marine waters, as it is generally considered to be available in insufficient quantities compared to phosphorus, and therefore potentially limiting plant growth. Recent studies, however, suggest that phosphate may be limiting in the marine environment under some conditions (Nixon; MERL), and is therefore important to consider as an input to coastal waters.

The growth of marine algae and plankton is not harmful in itself. Enrichment of estuarine waters with nutrients can provide a greater abundance of food at the base of the food chain for shellfish and juvenile fishes, some of which may be of commercial or recreational importance. Problems arise when algae or plankton become so prolific in the environment that they cannot all be consumed. As the algae die and decompose, the bacteria that decompose the plant tissues utilize oxygen in the water column, often times causing depletion of dissolved oxygen to levels that are below those required to maintain fishes and invertebrates. In extreme cases, fish kills result, which indicates degraded conditions most readily noticed in the form of odors from decaying plant and animal tissues. An excess abundance of nutrients in the water column can therefore stress and degrade the aquatic habitat. These conditions most often occur in late summer when dissolved oxygen content of estuarine waters is at a minimum due to natural conditions, and when aquatic plant metabolism is most intense due to warm water and increased light levels.

Overall, Mount Hope Bay does not exhibit symptoms that are normally associated with eutrophic conditions (i.e., algae blooms and fish kills). At the present time Mount Hope Bay and the Taunton River estuary do not appear to be compromised because of nutrient input to the main stem of the estuary, and long—term trends suggest that nutrient concentrations in the estuary have not changed greatly since 1975 (Desbonnet and Lee 1991). There have been, however, reports of algae blooms, fish kills, and other degradation of water quality reported for some of the smaller bays and coves that lead into Mount Hope Bay, such as the Lee, Cole, and Kickamuit Rivers. Some of the degradation occurring in these regions has been suggested to be related to nutrient inputs from improperly functioning ISDS in the estuarine subwatershed region.

Total Nitrogen

Total nitrogen (TN) is a measure of all forms of nitrogen. Not all forms of nitrogen are directly available to plants, however, but through various metabolic processes all the nitrogen present is eventually converted to a form that is usable by plants. Measures of total nitrogen availability are therefore the most meaningful way to consider input and potential impacts of nitrogen entering the estuary.

Of the assessed sources providing nitrogen to the Mount Hope Bay estuary, marine

Table 14. Total nitrogen loading to the Mount Hope Bay estuary in kilograms per year, and percentage of total and controllable loadings.

Source	Loading By Source	Total Loadings	Percent of Total Loading	Percent of Controllable Loading[1]
STPs[2]		596790	5	16
Somerset STP	44540			
Taunton STP	117900			
Fall River STP	434350			
CSOs[3]		49922	<1	1
Industry		na		
Taunton River[2]		919800	8	25
Runoff[4]		217236	2	7
Sub-Taunton Runoff	171513			
Sub-Mt. Hope Runoff	45923			
ISDS[5]		1859434	16	51
Boats		na		
Marine Sources[6]		7544550	76	na
East Passage	4982250			
Sakonnet River	2562300			
Atmosphere		na		
TOTAL LOADING		11187732		

[1] Percent of controllable loading refers to all sources except for the atmosphere and marine sources.

[2] From Pilson and Hunt (1989); Loadings for Taunton and Somerset STP are based upon the TN concentration derived from the Pilson and Hunt (1989) data.

[3] Estimated from Novotny (1991) concentration data; flow from Maguire Group (1987).

[4] Estimated from Schueler (1987); RIGIS (1992); MAGIS (1992); see Appendix ___ for sources of concentration data used in the loadings model.

[5] Estimated from Gold et al (1990).

[6] Estimated from modeled flow according to salt mass balance; see Appendix __ for details.

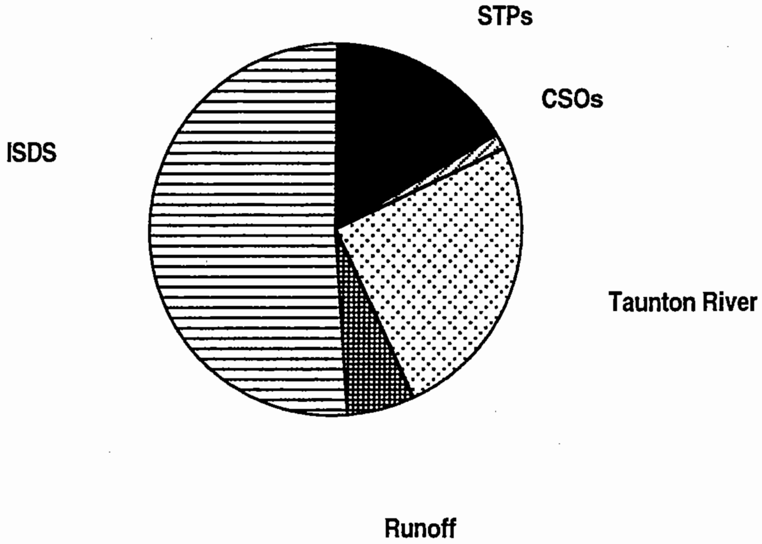


Figure 31. Contribution of total nitrogen to the Mount Hope Bay estuary from each of the controllable sources.

sources provide the largest proportion, contributing 76% of the total nitrogen entering the estuary (Table 14). ISDS provide the second largest contribution of nitrogen to the estuary (16%). The Taunton River, which is an accumulation of nitrogen from all the sources in thewatershed, provides the third largest source, contributing 8% of the total nitrogen load. Sewage treatment plants provide the fourth largest proportion of nitrogen to the estuary, contributing 5% of the nitrogen load.

The remaining assessed sources of nitrogen to the estuary are relatively minor in light of those already mentioned. Nonpoint source runoff provides only 2% of the total nitrogen load to the estuary, and CSOs comprise less than 1% of the total, making them only minor sources of nitrogen to the estuary. Atmospheric input to the estuary could not be directly compared to other sources due to differences in measured forms of nitrogen, but would most likely be a minor source of total nitrogen input to Mount Hope Bay.

Disregarding marine sources, which are considered uncontrollable at present, ISDS input is the largest controllable source of nitrogen to the estuary (51%; Figure 31). Of other controllable sources, the Taunton River provides 25%, STPs 16%, and runoff 7% of total nitrogen loading. CSOs provide only 1% of the total contollable nitrogen load.

Ammonia—Nitrogen

Ammonia—nitrogen is included in the total nitrogen loading estimates, but is an important form of nitrogen in estuarine waters. When ammonia is discharged to the bay, it is oxidized into nitrite and nitrate. This has two major consequences: 1) the oxidation of ammonia results in the depletion of oxygen in the water column, and 2) stimulation of plant growth which in turn may deplete dissolved oxygen if occurring in bloom proportions. The implications of this is that ammonia loading can potentially lead to degradation of water quality, and possibly to eutrophic conditions by depleting oxygen and promoting plant growth.

Of the estimated sources of ammonia entering the estuary, marine sources contribute the largest proportion (66%), while STPs provide 22% of the total load (Table 15). This figure (for STPs) may actually be a slight underestimate of the STP load since no data where available for the Somerset STP. Of the two STPs included, the Fall River STP provides 90% of that contributed to the estuary. The Taunton River is the third largest source of ammonia, providing 10% of the total load. Industry and runoff provide less than 3% of the total ammonia load, making them minor sources to the estuary relative to input by the STPs and the Taunton River.

STPs are the largest controllable source of ammonia to the estuary, providing 66% of the total (Figure 32). The Taunton River provides 28%, and runoff and industry combined provide 6% of the controllable ammonia loading.

Table 15. Total ammonia loading to the Mount Hope Bay estuary in kilograms per year, and percentage of total and controllable loadings.

Source	Loading By Source	Total Loadings	Percent of Total Loading	Percent of Controllable Loading[1]
STPs[2]		381665	22	66
Somerset STP	na			
Taunton STP	40403			
Fall River STP	341262			
CSOs		na		
Industry		2697	<1	1
Taunton River[3]		165000	10	28
Runoff[4]		30846	2	5
Sub-Taunton Runoff	24354			
Sub-Mt. Hope Runoff	6492			
ISDS		na		
Boats		na		
Marine Sources[5]		1149093	66	
East Passage	538083			
Sakonnet River	611010			
Atmosphere		na		
TOTAL LOADING		1729301		

[1] Percent of controllable loading refers to all sources except for the atmosphere and marine sources.

[2] From NPDES records; EPA Region I (1990).

[3] Estimated from Boucher (1991) concentration data;Pilson and Hunt (1989) flow estimates.

[4] Estimated from Schueler (1987); RIGIS (1992); MAGIS (1992); see Appendix ___ for concentration data sources used in the loadings model.

[5] Estimated from modeled flow according to salt mass balance; see Appendix __ for details.

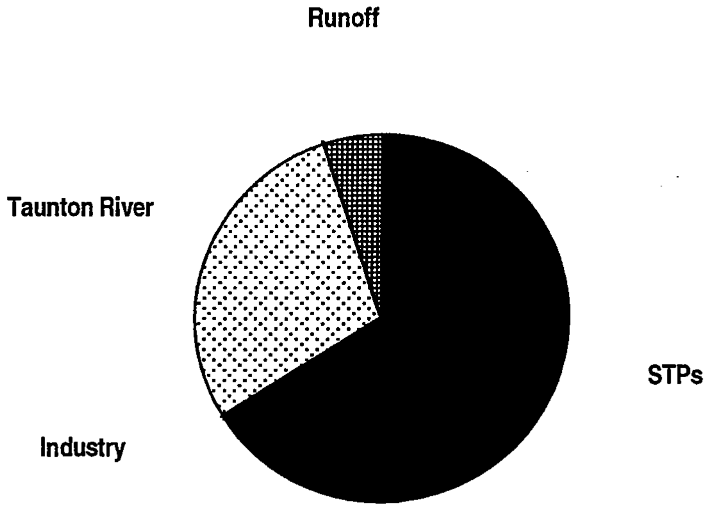


Figure 32. Proportion of ammonia co ntributed to the Mount Hope Bay estuary from controllable sources of input.

Table 16. Total phosphorus loading to the Mount Hope Bay estuary in kilograms per year, and percentage of total and controllable loadings.

Source	Loading By Source	Total Loadings	Percent of Total Loading	Percent of Controllable Loading[1]
STPs[2]		192386	7	51
Somerset STP	14280			
Taunton STP	37800			
Fall River STP	140306			
CSOs[3]		21420	1	5
Industry		na		
Taunton River[2]		147095	5	39
Runoff[4]		17663	1	5
Sub-Taunton Runoff	17100			
Sub-Mt. Hope Runoff	4558			
ISDS		na		
Boats		na		
Marine Sources[5]		2419950	86	
East Passage	1565850			
Sakonnet River	854100			
Atmosphere		na		
TOTAL LOADING		2798514		

[1] Percent of controllable loading refers to all sources except for the atmosphere and marine sources.

[2] From Pilson and Hunt (1989); Loadings for Taunton and Somerset STPs are based upon the TP concentration derived from the Pilson and Hunt (1989) data.

[3] Estimated from Novotny (1991) concentration data and flow from Maguire Group (1987).

[4] Estimated from Schueler (1987); RIGIS (1992); MAGIS (1992); see Appendix ___ for concentration data sources used in the loadings model.

[5] Estimated from modeled flow according to salt mass balance; see Appendix __ for details.

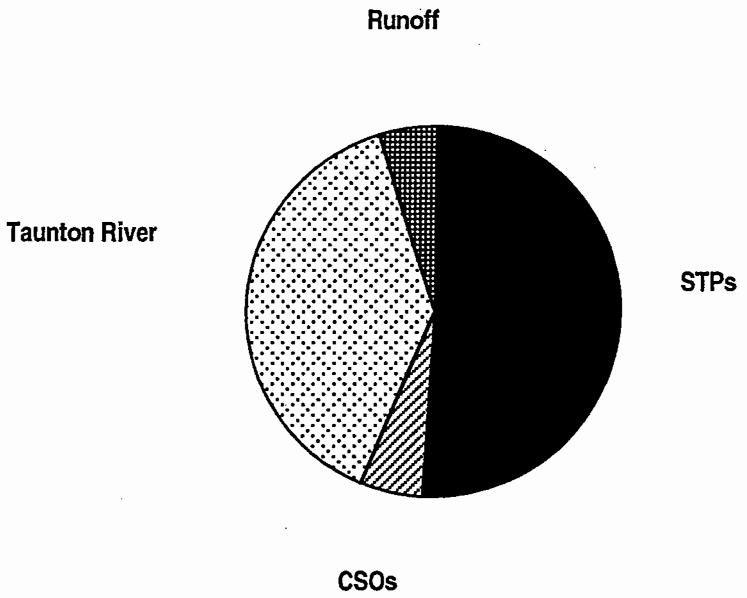


Figure 33. Contribuiton of total phosphorus to the Mount Hope Bay estuary from controllable inputs.

Total Phosphorus

Phosphorus, as a nutrient, is generally less worrisome than the input of nitrogen since it is typically not considered to be the limiting nutrient for aquatic plant growth in marine systems. Addition of phosphorus to the marine system, however, does ensure that this nutrient is available for use by plants as more nitrogen is made available, or in those instances where phosphorus may be limiting in the marine environment.

Marine sources comprise 86% of the total phosphorus entering the estuary of those sources for which TP estimates could be made (Table 16). The Taunton River contributes 5%, while runoff and CSOs provide a combined 2% of the total TP load. STPs contribute thesecond largest TP input, 7% of the total loading. Of controllable sources of phosphorus, STPs provide 51%, and the Taunton River 39% of the total controllable load (Figure 33). CSOs and runoff each provide 5% of the controllable load of phosphorus to the estuary.

Nutrients in the Water Column

Long-term measurements by MRI of nutrient concentrations in Mount Hope Bay suggest that there have been no clear increase or decrease in concentrations of dissolved inorganic nitrogen (DIN) in the bay between 1975 and 1985 (Desbonnet and Lee 1991). MRI ceased monitoring nutrients in 1985, and adding the DIN value, as calculated from the Pilson and Hunt (1989) SINBADD samples from 1985–1986 , to the MRI record, would suggest an increase in DIN between 1981 and 1986. However, the Pilson and Hunt values are based upon only 4 samples, two in the fall and two in the spring. The noted increase could therefore be a simple reflection of differences in sample time and frequency, so it is difficult to determine changes within the past 5-6 years time.

Boucher (1991) found that seasonally, total dissolved nitrogen was highest in February and lowest in April (Figure 34), and may roughly correspond to the availability and use by spring

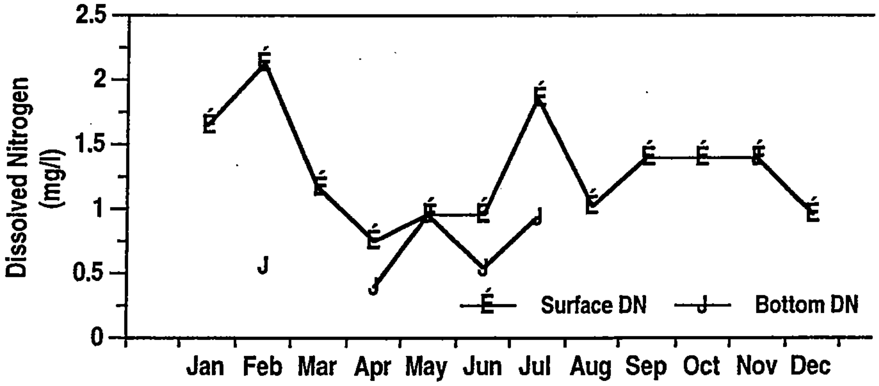
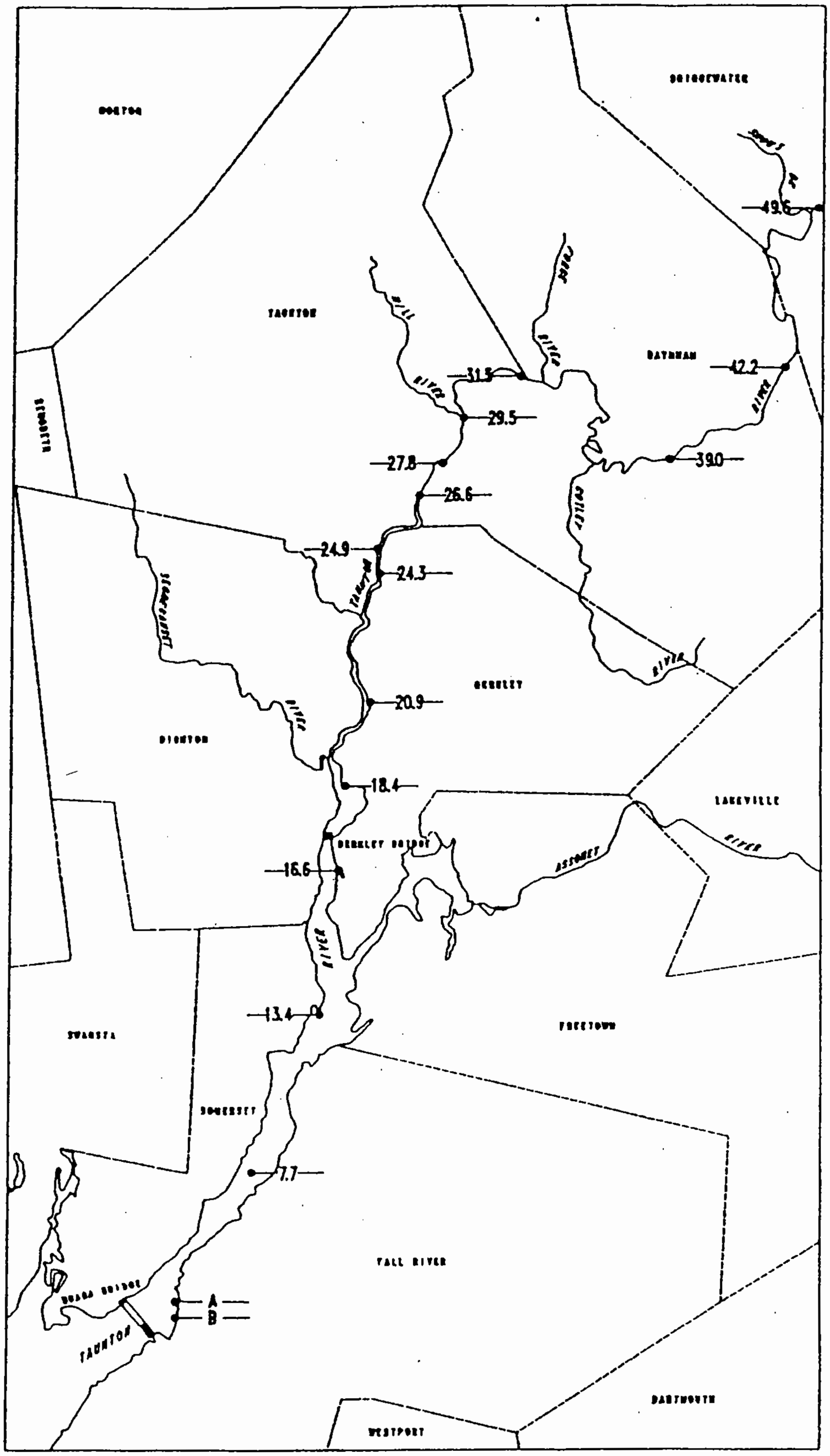


Figure 33. Seasonal abundance of total dissolved nitrogen in the tidal Taunton River during 1988–1989. Data are from Boucher (1991).



Map 4. Sampling points (and river kilometers) from Dorfman.

bloom phytoplankton, summer recycling, and the fall bloom. The abundance of nitrogen in the upper tidal Taunton River could not be attributed to river flow, and Boucher (1991) suggested that groundwater, runoff, and/or atmospheric deposition regulate the input of nitrogen to the estuary. Based upon calculated loading estimates for the estuary, it is reasonable to believe that the major source of nitrogen to the estuary is groundwater, which may be supplied by ISDS throughout the region. Boucher (1991) also found decreasing nutrient concentrations in down estuary transects (Map 3), suggesting that the Taunton River is the major nutrient supplier (via groundwater recharge), and Mount Hope Bay the major consumer, of nitrogen.

Ammonia concentrations measured along the length of the Taunton River show an interesting pattern (Figure 35). They decrease down river, until at a point 25 kilometers upstream of the Fall River STP site (near the city of Taunton, MA), at which point ammonia concentrations increase greatly, exceeding concentrations measured in the upper region of the watershed. The concentrations then decrease down bay, showing some increase in the region of the Fall River STP effluent discharge and the Fall River CSOs (Figure 35). The increase in ammonia concentrations in the area 25 kilometers up estuary of Fall River may be a reflection of the discharge from the Taunton STP or other sources in the Taunton municipal area.

Long-term trends in phosphorus concentrations in Mount Hope Bay suggest some decrease over time, particularly since 1980 (Desbonnet and Lee 1991). This reduction could be a result of improved sewage treatment, considering that STPs are calculated to be the major provider of anthropogenic phosphorus to the estuary. However, phosphorus is not routinely measured by the STPs, and therefore this cannot be further quantified. Boucher (1991) found total phosphorus to decrease down estuary, and follows a pattern similar to that noted for ammonia (Figure 36). Total phosphorus concentrations tend to decrease rapidly once within the estuary, and is most likely due to mixing and dilution in the dynamic estuary, and does not show an increase in the Fall River area as with other nutrients.

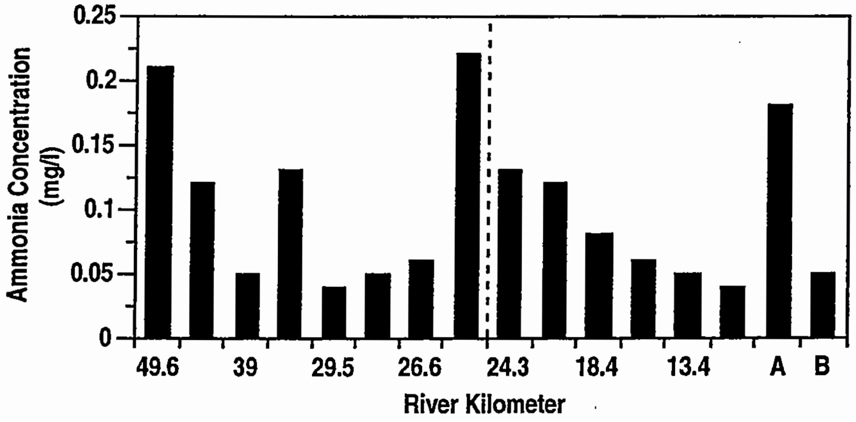


Figure 35. Concentrations of ammonia along a down estuary transect in the Taunton River. Data are from Dorfman (1986). A is above the Fall River STP effluent discharge site, B is below. The vertical dashed line marks the head of tide and the approximate location of the city of Taunton, MA.

The foremost controllable inputs of nitrogen are ISDS in the estuarine subwatershed region. The input of ISDS may be particularly important in arms of the estuary, such as the Lee, Cole, and Kickamuit River areas. These regions have recently experienced adverse water quality conditions in the form of algae blooms and fish kills, whose cause has generally been related to ISDS problems (Riposa pers comm). Clearly, some form of plan for the management of ISDS discharge into groundwater and the estuary will be required to ensure that nitrogen input to the estuary does not result in conditions typical of eutrophic waters in the greater part of the Mount Hope Bay estuary.

The Taunton River, along with STPs, provide further controllable input of nitrogen to the estuary. The Taunton River nitrogen load to the estuary is a reflection of all the sources, point and nonpoint, contained within its watershed. A reduction in the load of nitrogen supplied by the Taunton River therefore, will only be gained by development of nutrient control measures throughout the entire watershed. Implementation of nonpoint and ISDS control measures in the watershed of the Taunton River could result in reduced nutrient input to the estuary, a measure which may also be good for the river itself if nutrient related problems are noted for the Taunton River or adjacent groundwater supplies. It would be expected that nonpoint runoff and ISDS would be the major sources of nutrient input to the Taunton River and its tributaries in the watershed. Further control of nitrogen to the estuary from STPs may only be gained through expensive retrofit of the current facilities to tertiary treatment or denitrification. Considering that the Fall River STP provides 73% of the nitrogen input from STPs, this facility should be a first consideration for technological change to reduce nutrient input should eutrophication of Mount Hope Bay be documented in future studies.

Control of nitrogen movement from ISDS to the estuary can be gained by better management and regulation of siting, construction, and maintenance procedures, replacing failed systems with modern and/or innovative system designs, or extending sewers to those

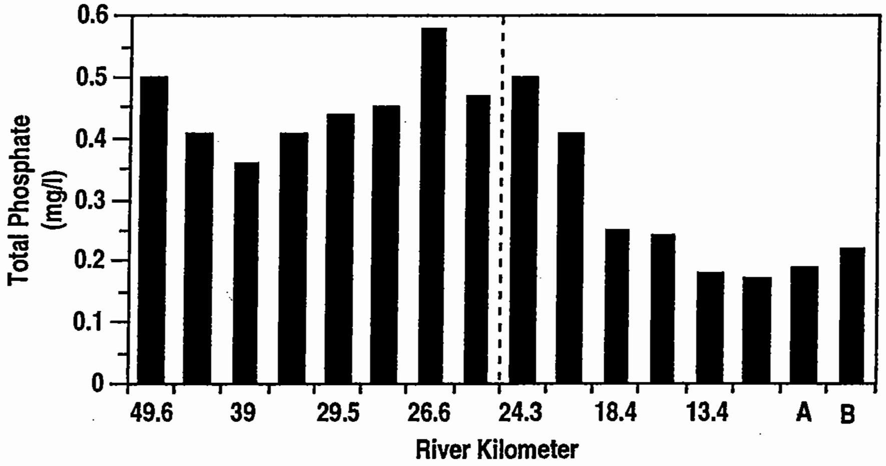


Figure 36. Total phosphate concentrations along a down estuary transect in the Taunton River. Data from Dorfman 1986. A is above the Fall River STP effluent discharge site, B is below. The vertical dashed line marks the head of tide and the approximate location of the city of Taunton, MA.

regions of the subwatershed that have reasonable access to the treatment facility, and where there is some desirability in extending the municipal sewer system to these regions. A most effective way to reduce and control the input of nitrogen from ISDS is to decrease the density of septic systems in the watershed by changing present zoning. In order to effect this type of change, it may be necessary for towns within the watershed to evaluate and rewrite existing plans of development, zoning laws, and comprehensive plans.

In summary, nutrients are not at present noted to be problematic, or responsible for conditions that are commonly reported of eutrophic marine systems, throughout the large majority of the estuary. Several smaller, more poorly flushed arms of the bay, such as the Lee, Cole, and Kickamuit Rivers, have been noted to exhibit conditions that could be related to an over abundance of nutrients. Within the subwatershed regions of these arms of the estuary, an interstate effort, such as that described earlier for the control of sources of fecal coliform bacteria, should be undertaken to reduce the flow of nutrients into these susesptible bodies of water.

These efforts should be conducted by RIDEM and MADEP, in cooperation with the Interstate Committee, and should focus on reducing nutrient loading within the subwatersheds to the Lee, Cole and Kickamuit Rivers. The major emphasis should be upon the control of ISDS and runoff inputs to these bodies of water. The two state agencies should work together to identify regions of failed septic systems, poorly drained sites, areas with a high water table, and soils that are not condusive to the proper functioning of ISDS.

Plans should be developed on a regional scale that will address the nutrient input problem to these arms of the bay by identifying and prioritizing areas for the expansion of sewers, where the incidence of failed or failing systems is greater than expected, and where conditions are equitable for the implacement of novel or innovative system designs. Funds should be sought to underwrite the costs of sewer expansions and/or for the introduction of upgraded ISDS technology. Sections 04–01–02 Source Reduction: Nutrients; 04–01–05 Source Control: On–Site Sewage Disposal Systems; 04–01–07 Source Reduction: NonPoint Source; 04–02–01 Land Use; and 04–02–04 Public Health further describe initiatives that need to be reviewed and implemented by respective state agencies. These should be conducted through the Interstate Committee because nearly all the components of source reduction and control will require interstate efforts in order to achieve improvement.

A Summary of Pollutant Loadings and Impacts in the Mount Hope Bay Estuary

At present, the single greatest concern with regard to water quality in the Mount Hope Bay estuary is contamination of waters with fecal coliform bacteria. Although this is typically not a concern from an ecological point of view, it does have consequences for human use of the resource. Contamination with fecal coliforms has consistently kept Mount Hope Bay closed to shellfishing since the middle of this century. It is now known that the CSOs located in the Fall

River area are the source of greatest bacterial input to the estuary. As such, abatement of CSO discharges into the Taunton River—Mount Hope Bay estuary should be the foremost action taken with regard to improving water quality and use of the estuary. The city of Fall River has implemented controls for dry weather discharge from CSOs, and has drafted plans for the control of wet weather discharges. These plans (wet weather) should be finalized and implemented. Although it is impossible to definitively say that shellfishing in Mount Hope Bay will be allowed once the CSO problem has been corrected, there is reason to believe that harvest could take place on a conditional to rainfall management basis. If not, correction of the CSO problem will allow other sources which may be presently masked by the CSO discharges to be identified, located, and abated.

Furthermore, the discharge of CSOs into the Fall River region of Mount Hope Bay may be related to the sanitary quality of waters in the Kickamuit River, and possibly within the Lee and Cole Rivers. If this is so, then the overall degradation effected by CSOs upon the estuary is large, and far reaching in its impact. If the circulation and flushing patterns and dynamics of the estuary are responsible for the transport of fecal coliforms from the Fall River area into the Lee, Cole, and Kickamuit Rivers, the only way to fully control the sanitary quality of these arms of the bay are to control and abate the Fall River CSOs.

Sources other than the CSOs, however, are responsible for at least some portion of the observed fecal coliform bacteria in the Lee, Cole, and Kickamuit Rivers. For this reason, further study and monitoring in these regions will be required to determine proper control and management strategies. Since the land and water resources of two states contribute to the problem, and to the solution of fecal coliform contamination of Mount Hope Bay and its arms, interstate efforts at planning and management will be required to arrive at a solution that is not only adequate for the improvement of the resource, but one that is affecting similar changes across state and juristictional boundaries.

Observed on an averaged annual basis for the month of August only (assumed worst case conditions), concentrations of dissolved oxygen in Mount Hope Bay have not been problematic since at least 1972, at least with regard to anoxic or hypoxic conditions. In fact the frequency of low dissolved oxygen conditions, as well as low oxygen saturation of the water column, are decreasing over time. Oxygen concentrations in bottom waters of the bay and tidal river, however, do not consistently meet the criteria for Class SA or SB quality waters. Oxygen concentrations in Mount Hope Bay therefore may be viewed as problematic with regard to meeting Clean Water Act mandates. Mean bottom water dissolved oxygen content in the months of July and August falls below 5.0 ppm, the EPA standard considered able to support a healthy and diverse marine community. Low dissolved oxygen in bottom waters of the bay may be a natural phenomenon such as is seen in other statified estuaries. However, little is known about the extent and persistence of low dissolved oxygen in Mount Hope Bay bottom waters, nor if the seasonal fluctuations measured over time are simply representable of natural background condtions. Further study of this would assist in understanding potential impact of low dissolved oxygen events upon the aquatic fauna of the bay, as well to the origins of the events and potential solutions if needed. This information would also help determine if the waters of the Mount Hope Bay estuary can, or are, meeting the mandates of the Clean Water Act despite measurements of oxygen in bottom waters that are less than 5.0 mg l-1 during a restricted time of the year.

Reductions in BOD loading and ammonia to the estuary as part of management actions for runoff control, CSO abatement, and providing good secondary treatment processing at STPs may help further improve dissolved oxygen content of waters in Mount Hope Bay and the tidal Taunton River. Control of CSO discharges could reduce BOD loading by 20%, while control of nonpoint source runoff could reduce loading of BOD by another 23%. These control measures will be more important in localized areas where problems have been documented, such as the Lee, Cole, and Kickamuit River areas. If the observed low dissolved oxygen concentrations in the bay and tidal river are the result of natural occurances, then reduction of BOD and TSS input to the system may have insignificant effect upon measured dissolved oxygen conditions in the estuary.

Metals are not presently problematic in the Mount Hope Bay estuary. Concentrations of metals measured in Mount Hope Bay waters do not exceed those considered toxic to marine organisms by the EPA for either long—term or short—term exposure on a regular basis. However, metals that have accumulated in sediments may present problems with regard to the restriction of dredging and/or the disposal of dredged spoils. A major concern for metals and toxics in the estuary will therefore arise when dredging operations are proposed in the estuary and decisions about dredge spoil disposal must be made.

Although at present there are no criteria by which to assess or judge the potential impact of metals concentrations contained in marine sediments upon benthic organisms, future establishment of guidelines and criteria by EPA will allow for this type of comparison. At that point, better reference will be able to be made with regard to sediment quality of Mount Hope Bay and the tidal Taunton River. However, drastic reduction of metals concentrations in the waters of the Mount Hope Bay estuary are not required to acheive water quality standards. Considering the occassional exceedance of EPA chronic criteria for certain metals, it would be prudent to control for future increases in metals discharges to the estuary as protection against causing conditions that are harmful to marine life.

Although nutrient abundance in Mount Hope Bay does not appear to be problematic at the present time, caution should be used in allowing further nutrient input to the bay, if for no other reason than to be prudent in the long—term management of the resource. Unfortunately the concentrations and/or loadings at which nutrients, particularly nitrogen, become abundant enough to cause problems typically associated with eutrophication (e.g., algae blooms, fish kills) are not known. It is therefore extremely difficult to determine what is enough, too much, or too little with regard to nutrient input to coastal waters. Because of this lack of understanding, no regulatory criteria yet exist by which to set standards and limits on nutrient inputs to estuarine waters.

The greater the nutrient concentrations and loadings to the estuary, the greater the risk of eutrophication occurring. In consideration of so many unknowns, the most reasonable path to follow is one of moderation with regard to the input of nutrients to the Mount Hope Bay estuary. Septic systems located in the subwatersheds of the estuary are the major source of controllable nitrogen, and ISDS systems in the Taunton River watershed no doubt contribute to the nitrogen load entering the estuary from the Taunton River. Better control and management of septic systems and nonpoint source runoff in the Taunton River watershed, as well as the estuarine subwatershed areas, could reduce the input of nitrogen to the estuary by as much as 50%. Implementation of management practices for nonpoint runoff and ISDS maintenance and repair is much more cost—effective than spending billions of dollars for conversion of treatment plants to tertiary processing of wastes, and gives a greater reduction of nutrient input overall. Considering that nutrient problems do not exist at present, management aimed at controlling and reducing the input of nitrogen from ISDS and runoff in the watersheds of the estuary could result in avoiding the need for expensive STP upgrades, as is presently being proposed for the nearby Long Island Sound estuary. Development and implementation of plans to control runoff and ISDS input would be directly applicable to regions with documented problems related to these sources, such as the Lee, Cole, and Kickamuit Rivers. In order to accomplish a reduction in nutrient loading to the estuary in these regions, changes in zoning to larger lot sizes and lower densities of ISDS, and new ISDS technology, such as denitrification systems, should be explored and implemented where practical. Denitrification ISDS are expensive, and an economic outline of the costs, as well as potential funding sources will need to be developed.

SOURCES OF POLLUTANT AND NUTRIENT INPUTS TO THE MOUNT HOPE BAY ESTUARY

There are six principal sources of pollution input to the Mount Hope Bay estuary; rivers, combined sewer overflows (CSOs), sewage treatment plant discharges (STPs), industrial discharges, boat sewage discharges, urban runoff, the atmosphere, and Narragansett Bay. A brief description of the major sources in each of these categories is given here as background information. Each source is described in detail, and the methods of estimating pollutant inputs to the Mount Hope Bay estuary from each source is provided.

The Taunton River

The Taunton River is the largest tributary and source of freshwater to the Mount Hope Bay estuary, providing 85% of the freshwater input. The large volume of freshwater delivered to the estuary by the river, estimated at 1.64×10^9 liters per day (Pilson and Hunt 1989), plays a major role in shaping the circulation and flushing patterns of the Mount Hope Bay estuary (Spaulding and White 1990).

For the purpose of simplicity in estimating pollutant and nutrient loadings to the Mount Hope Bay estuary, the Taunton River is treated as a point source discharging into the estuary. Measured concentrations of pollutants and nutrients, taken as close to the junction of the tidal/non-tidal portion of the river are used to calculate loadings based on river flow. Because the Taunton River is not gauged to measure flow or monitored for other water quality parameters at its junction with the estuary, measures of water quality parameters taken as far up estuary as possible are used, and combined with an estimated flow to calculate pollutant loadings from the river. River flow was estimated by Pilson and Hunt (1989) by integrating runoff in the nongauged portion of the watershed, and adding this to the measured flow at the USGS station, which gauges approximately 50% of the river flow at Bridgewater, Massachusetts. The estimated total flow is then used to calculate pollutant loadings based upon concentration data taken from a variety of sources, and a variety of station locations throughout the estuary.

Discharge to the estuary (defined here as the tidal portion of the Taunton River and Mount Hope Bay) by the Taunton River is the sum total of all discharges in the watershed, and takes into consideration dilution, and the physical, chemical, and biological processes that remove or transform pollutants as they move through the watershed and river system prior to entering the estuary.

Despite the important effect of the Taunton River on the Mount Hope Bay estuary, very few recent comprehensive studies have been performed in the nontidal river. Long-term monitoring data do not exist by which to fully assess the impact of the river on the estuary, nor to look at long-term trends in riverine water quality. Two recent studies do provide useful measures of nutrients, metals, or hydrographic parameters: the 1985–1986 SINBADD cruises (metals, nutrients) as part of the Narragansett Bay Project research initiatives in Mount Hope Bay and the tidal Taunton River (Pilson and Hunt 1989), and a 17-month study in the tidal Taunton River of nutrients, temperature, salinity, and dissolved oxygen as part of a doctoral thesis undertaken by Boucher (1991). The assessment of pollutant and nutrient input from the river to the estuary relies heavily upon data reported in these studies.

CSOs (Combined Sewer Overflows)

Sewer systems that were constructed during the early portions of the twentieth century typically were designed to divert excess flow from the treatment facility during heavy rainfall events. This design avoided over-burdening the treatment facility with more wastewater than it was designed to handle by allowing overflow volume entering from stormwater drains to be diverted directly to receiving waters. The diverted flow, however, was typically discharged into the nearest convenient waterway, and was a mixture of stormwater and untreated sewage, which often was a cause of water quality degradation in the bay.

The city of Fall River is the only municipality in the Mount Hope Bay estuary to possess a CSO system, which comprises a total of 19 CSO discharge points. Of the 16 CSOs addressed in this assessment, 4 discharge to the Taunton River, 5 discharge into Mount Hope Bay, and the remaining 7 CSOs discharge directly into the Quequechan River which then drains into the bay (Maguire Group 1989). CSO input was calculated using flow and concentration data provided in Maguire Group (1989). Various other sources were used to gain estimates of pollutant concentrations not given by the Maguire Group study. Loadings were then calculated using actual flows given in Maguire Group (1989).

CSOs are noted to be major sources of water quality degradation where they exist, generally limiting use of the aquatic system for swimming and shellfishing due to the high fecal coliform input from their untreated sewage discharges. Because of their high visibility as a major source of water quality degradation, CSO discharges have recently come under pressure for remediation. The city of Fall River has recently completed a major study of the CSO problem, and has developed a plan for the abatement of CSO discharges to the Taunton River, Quequechan River, and Mount Hope Bay. Phase I of the plan is to eliminate dry weather discharges (completed), while Phase II will address the correction of wet weather flow to the estuary (under review).

Marine Sources

Oceanic input of pollutants and nutrients to coastal estuarine waters has historically been considered minor. Contemporary work by Pilson (1984) and Nixon and Pilson (1984), and Nixon (In prep), has shown that the oceanic input of nutrients to coastal waters can be significant. In the context of coastal management, the input of pollutants and nutrients to coastal waters from the ocean may be as large as, or larger than, land based loadings. Although concentrations of nutrients and pollutants in oceanic waters are generally small, volumes of tidal and nontidal mixing are large, making nutrients available on a consistent basis with each incoming tide. Input of nutrients and pollutants to the Mount Hope Bay estuary from Narragansett Bay are considered in this assessment, even though abatement of loadings from Narragansett Bay are beyond the scope of present management initiatives.

Tidal flushing and nontidal estuarine flow into the Mount Hope Bay estuary occurs from Narragansett Bay via the East Passage under the Mount Hope Bridge, and from Rhode Island Sound via the Sakonnet River. The exchange between these bodies of water occurs continuously as salt water is entrained along the bottom into Mount Hope Bay as fresh water flows out on the surface of the bay. Determination of the input of nutrients and pollutants to the Mount Hope Bay estuary from marine sources is also a function of twice daily tidal exchange.

The tide in Mount Hope Bay has been described by Spaulding and White (1990) as a standing wave, and the tidal volume estimated by Chinman and Nixon (1985). However, estimates of pollutant loadings based upon tidal exchange have not been published. To account for this loading, a simple box model was used to calculate a mass balance for salt in Mount Hope Bay. The volume of input was determined from the box model to be 5.74 x 10^{10} liters per day (see Appendix __), approximately 80% of the tidal volume given by Chinman and Nixon (1985). In order to determine relative input to Mount Hope Bay from the East Passage and the Sakonnet River, the percentage of tidal flow through each opening given by Swanson and Jayko (1988) was used. An estimated 68% of the exchange volume is through the opening to the East Passage of Narragansett Bay, or 3.9 x 10^{10} liters per day. This leaves a volume of 1.8 x 10^{10} liters per day exchanged via the Sakonnet River.

Concentration measurement data for nutrients and metals reported by Pilson and Hunt (1989), were used to determine the input from each marine source. The data given by Pilson and Hunt (1989) were averaged for all 4 sample cruises (Oct/Nov 85; Apr/May 86) and for each measured depth, to provide averaged concentration data for each nutrient and metal. Data for the East Passage are taken from their Station 12, and for the Sakonnet River from Station 19. Multiplication of volume times flow provides loading estimates to the estuary. The calculated input to the estuary is a first—order estimate which disregards complicating factors such as tidal pumping, and wind driven mixing, and does not account for export out of Mount Hope Bay. It does, however, provide a useful estimate of the contribution of nutrients and pollutants from marine sources, and gives some sense of background level loadings to the estuary.

Nonpoint Runoff

Nonpoint derived pollutants and nutrients enter the estuary from the runoff of rainwater over land surfaces. The runoff picks up various pollutants and nutrients deposited on land, and transports them according to surface topography, eventually depositing the accumulated load in a stream, river, lake, wetland, or coastal region. The concentration of pollutants is related to land use, generally having higher concentrations in more developed, urbanized areas. Pollutants are also filtered from the runoff water, the degree of filtration being based upon the permeability of soils. Permeability is generally reduced in highly developed, urbanized areas, resulting in these regions providing the greatest nonpoint runoff derived pollutant loadings.

For the purpose of assessing the loading of runoff delivered pollutants to the estuary, the watershed area is divided into three distinct regions; 1) the entire watershed draining into the non-tidal Taunton River; 2) the subwatershed draining directly into the tidal portion of the Taunton River; and 3) the subwatershed area draining directly into Mount Hope Bay (Maps 4 and 5).

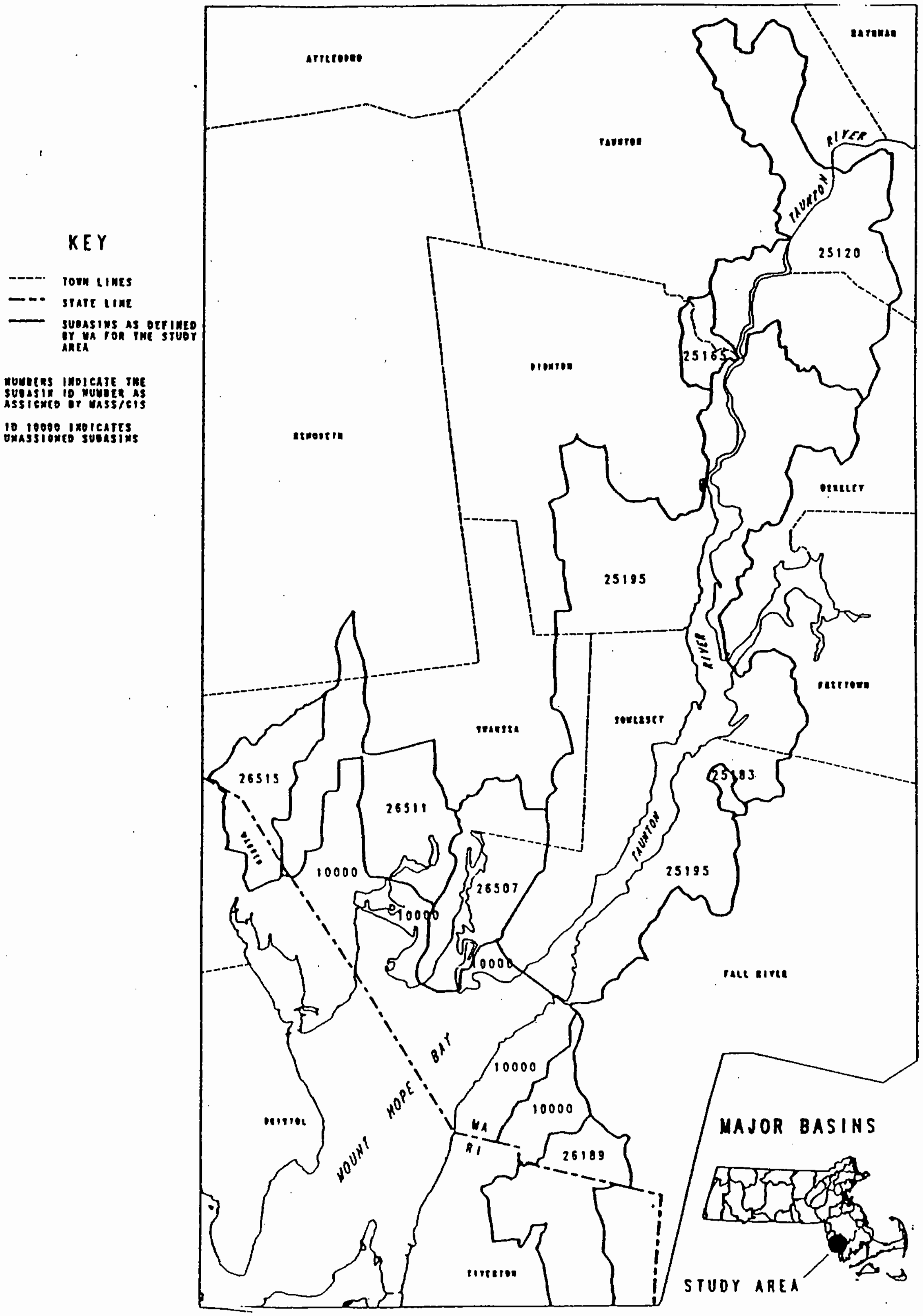
Runoff draining from the upper watershed to the Taunton River is assessed using the measurements reported by Pilson and Hunt (1989) and Boucher (1991), and is incorporated as part of the Taunton River loading described earlier in this section. Runoff loadings directly to the estuary are combined for that entering the tidal portion of the river and those to Mount Hope Bay. Separate loading values for each of the two loading regions are provided in tables for comparison purposes. Calculation of nonpoint source runoff loadings were performed according to a model reported by Schueler (1987). Details of this model and sample calculations are given in Appendix ___. Loadings data, according to land use type and area are provided in detail in Appendix ___. A large format land use map is on file at the Urban Harbors Institute. Nonpoint runoff data for the Taunton River watershed are also provided in Appendix ___ for future use in management of the watershed, but are not directly used in this assessment.

ISDS (Individual Septic Disposal Systems)

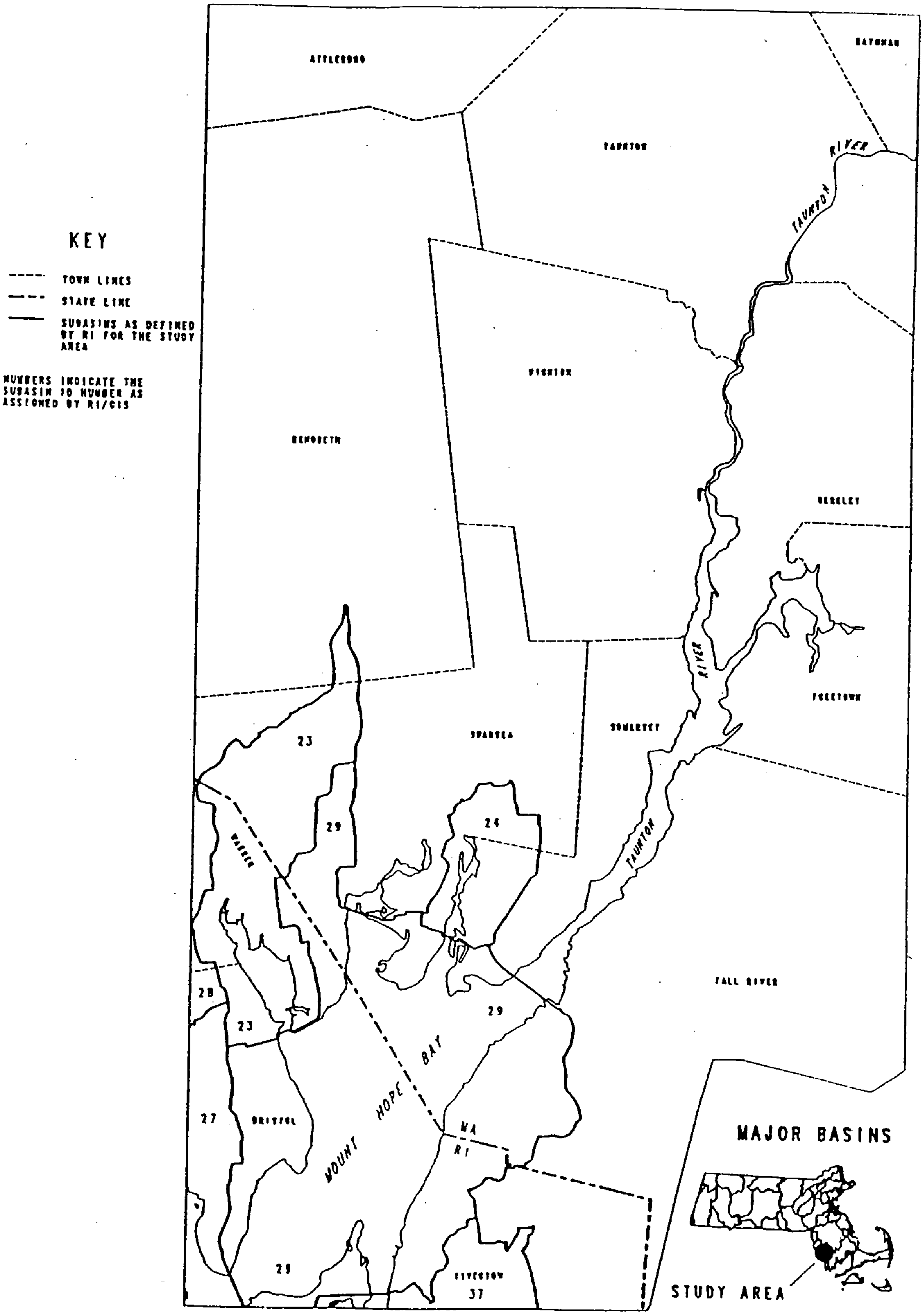
ISDS are the means for processing human sewage wastes in those regions where sewers and municipal sewage treatment facilities do not exist. ISDS regularly leach nutrients and pathogens into the ground, where they may enter groundwater systems and travel great distances (REF). In general, most pathogens, metals, and phosphorus become bound to soils or die off (bacteria) within a relatively short distance from the ISDS site (REF). Viral pathogens may travel long distances and remain viable (REF), but not enough is known of this phenomenon to enter into this assessment at present.

In properly designed and functioning ISDS, the organic ammonia nitrogen is rapidly converted at the ISDS site to nitrate—nitrogen, which travels great distances in groundwater with potential impacts upon drinking water supplies, rivers, streams, and coastal marine systems. Since nearly all nitrogen leaving the ISDS site is in the nitrate—nitrogen form, ISDS loading to the estuary is assessed as total nitrogen loading (TN) for the purposes of this assessment.

Housing unit numbers within the two subwatershed regions of the estuary that are not serviced by municipal sewer systems were gathered from several sources (see Appendix ___) in order to assess the loading of nitrogen to the estuary from ISDS sources. A model developed by Gold et al., (1989), is used to estimate the nitrate—nitrogen loading, as TN, from ISDS in the estuarine subwatershed each year. Details of the model are given in Appendix ___.



Map 4 Subbasins in the study area as defined by the Commonwealth of Massachusetts.



Map 5 Subasins in the study area as defined by the State of Rhode Island.

The Atmosphere

Atmospheric deposition onto the water surface can be a considerable source of pollutants and nutrients to bodies of water. Atmospheric deposition of pollutants and nutrients directly to the estuary were derived using deposition rates reported in Nixon (1990), and surface water area of the Mount Hope Bay estuary (RIGIS 1992; MAGIS 1992).

Although atmospheric input generally tends to be small, it must be considered as a constant and uncontrollable (e.g., not easily abated) source in the immediate management area. Much like the input from marine sources, those nutrients and pollutants added to the estuary from atmospheric sources must be considered as background level loadings, and whose control is beyond the scope of present management initiatives.

Boats

Boats that are moored in or visit the Mount Hope Bay estuary have the potential to cause some impact upon water quality. This impact is generally considered to be delivered from the discharge of human sewage wastes into an estuary, such as the Mount Hope Bay estuary, where boat sewage pumpout facilities are not available.

An estimated 2,000 boats exist in wet storage (at docks, moorings, or slips) in the estuarine management area (Amaral pers comm). The impact of boats with regard to fecal coliform input is generally small when assessed over the total volume of an estuarine system the size of the Mount Hope Bay estuary (approximately 2 MPN/100 ml based on 2000 boats), and result in concentrations that do not prohibit shellfishing or swimming uses when assessed in this manner. There is, however, the potential for contamination of waters to a degree that could limit use for shellfishing, and possibly swimming, in localized areas, particularly in poorly flushed coves and bays that harbor large numbers of moored and/or docked boats with marine toilets. For the purposes of this assessment, boat sewage input is assessed on an estuary wide basis according to fecal coliform input relative to other known sources. There is a general lack of sufficiently detailed data to assess the impact of fecal coliform loading to specific, localized areas of the estuary. The model developed by the NSSP (National Shellfish Sanitation Program; HEW 1988) is used here to calculate the estimated fecal coliform loading from boats to the estuary. Beside the assumptions inherent to the model (see Appendix __), it is assumed that all 2000 boats have heads, that a 25% occupancy rate of boats occurs, on average, and that the boating season is from June through September (120 days).

Industry

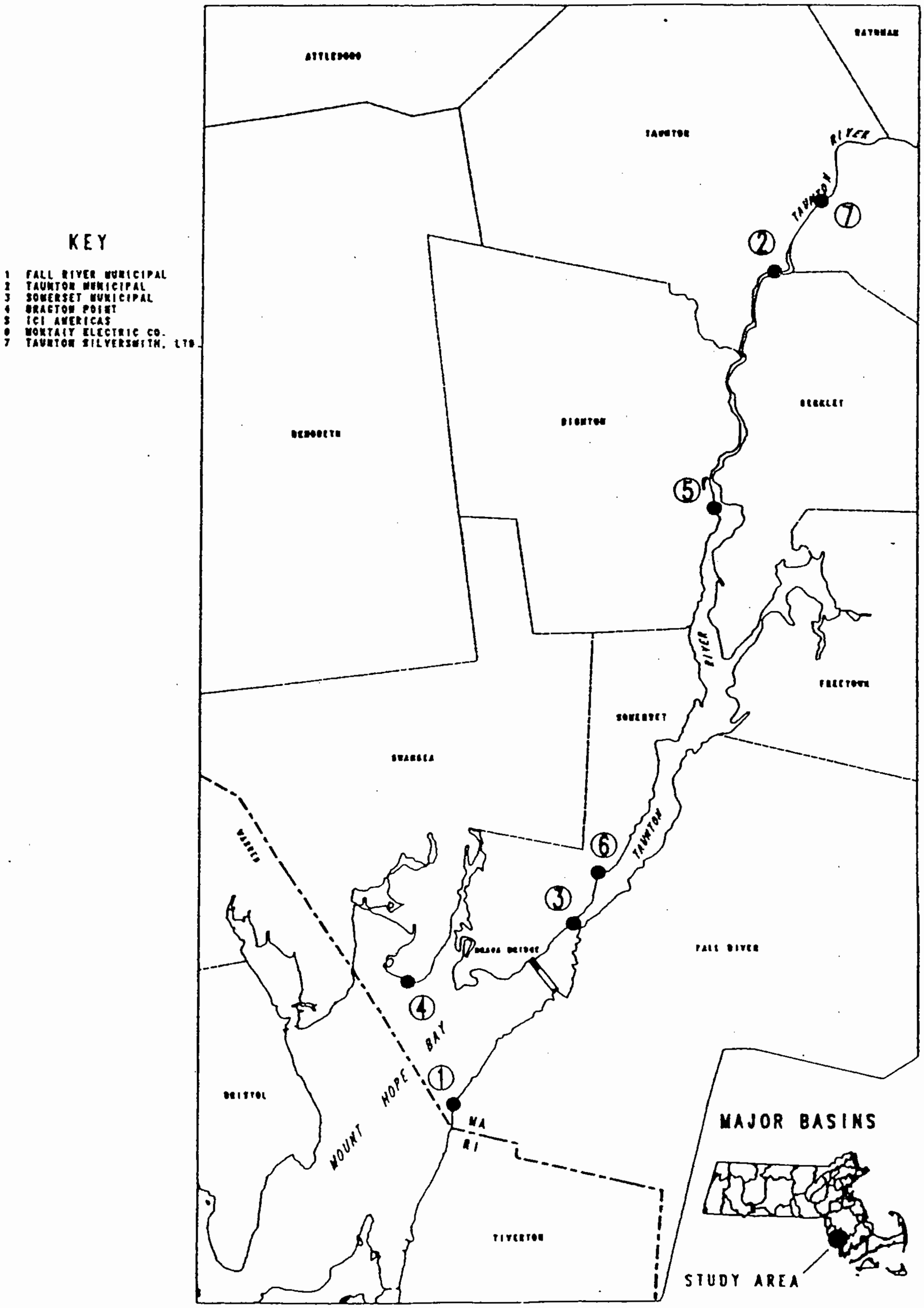
Industry and manufacturing have been significant historical uses of the land area surrounding the Mount Hope Bay estuary since the beginning of the Industrial Revolution in this country. Although industry has generally declined throughout the Narragansett Bay region in recent times, a number of industrial firms still exist in the region surrounding the estuary. Of these industries, only those that have permitted wastewater discharges directly to the Mount Hope Bay estuary are assessed here. The following industries have permitted discharges as part of NPDES (National Pollution Discharge Elimination System) regulations, and are included in the assessment of industrial discharges to the estuary; I.C.I. Americas, Inc., Montaup Electric Company, Taunton Silversmiths Ltd, and New England Power Company (Brayton Point) (Map 6). Other industries discharging into the Taunton River watershed are incorporated in loading estimates for the Taunton River as it enters the estuary.

STPs (Sewage Treatment Plants)

Sewage treatment plants were constructed, generally in the larger and more heavily populated metropolitan regions, to process human sewage and domestic wastewater that at one time was discharged directly into rivers, streams, and bays. The general filthy conditions, and threat to human health from the discharge of untreated wastes, forced the construction of STPs to abate this source of contamination.

Three major STPs are presently located within, and discharge directly to, the Mount Hope Bay estuary. These three, from smallest to largest are; Somerset STP (1.6 MGD), Taunton STP (___MGD), and Fall River STP (31.3 MGD) (Map 6). The Somerset and Taunton facilities discharge directly into the tidal portion of the Taunton River, and the Fall River facility discharges directly into the northeast corner of Mount Hope Bay. Each of the facilities processes sewage wastes to secondary treatment standards, and maintains self-monitoring records for a variety of discharge parameters as part of their NPDES requirements. The loadings from all three facilities are assessed as a sum total with regard to loading and other sources in the assessment. However, loadings for each STP are provided in loadings tables for comparative purposes. Loading is calculated by multiplying effluent flow of the STP times measured concentrations, both taken from NPDES monitoring records. Concentration estimates were taken from non—NPDES sources when not available from monitoring records.

Flow from the Fall River STP has increased from 19 MGD in 1983 to 31 MGD in 1989–90 and the facility is now operating at its design capacity (31.3 MGD; NPDES Records). Infiltration and inflow of groundwater to the system is reported to make up 50% of the flow to the facility on a dry day (Sullivan 1990), suggesting that the facility is processing a greater volume of wastewater than is necessary, and than designed to properly treat (Maguire Group 1990). The inflow and infiltration to the plant will present problems if and when new areas are to be connected to the municipal sewer system. Either the facility will have to be redesigned to handle larger influent volumes, or the infiltration problem will need to be corrected prior to increasing the volume of wastes treated by the facility.



Map 6. NPDES permitted industrial and municipal sewage treatment plant discharges in the study area.

RECOMMENDATIONS FOR THE CONTROL OF NONPOINT SOURCE POLLUTION

The federal government has recently released, or is planning for the near future release of standards, guidance, and criteria for use by states in the development of nonpoint source pollution control and abatement programs. Section 319 and 6217 are the most recent guidance released to states for interpretation and adoption. Since the management and planning for nonpoint source control is a mandate that must be met by each of the states with regard to Sections 319 and 6217, the states of Massachusetts and Rhode Island will need to begin to interpret and implement nonpoint source controls in the very near future.

As the states of Massachusetts and Rhode Island begin their planning process for the control of nonpoint sources, an **Interstate Committee** should oversee and coordinate nonpoint source control planning for those watersheds and subwatersheds that are common to both states. The planning process should involve both state agencies (RIDEM/MADEP), with the goal being to arrive at a comparable method of controlling nonpoint sources within the interstate watershed. The planning process should involve consideration of impacts of nonpoint source pollution upon the quality of receiving waters, but should also incorporate present land use patterns, future planned uses of lands within the watershed, the spatial pattern of land use within the watershed, and where critical areas are located in relation to regions of heavy use and development in the watershed.

An example of a program for use at the town and state level is a nonpoint source management module that is presently being developed by the Connecticut Sea Grant and Cooperative Extension Service. The management module relies heavily upon GIS data systems, and uses land use data to develop a series of "snapshots" that show resource managers where critical resource area exist, what present zoning patterns are, what areas of the watershed have already been developed, and what zoned areas are available for development in the future, as well as their relationship to other zoning and land use types.

The module allows for interaction between managers and their resources, availing views of current patterns of development within the watershed, as well as what the layout will look like in the future given changes under consideration for implementation. This interactive approach will be most useful on an interstate level of management, as it will allow for the easy observation of land use within the watershed, regardless of interstate boundaries, as well as allowing for the rapid observation of proposed changes in zoning and land use across state boundaries within the watershed. A much more refined method and level of planning can be obtained using this method, and should result in a much reduced level of conflict between states and/or towns with regard to zoning, land use, and future compatibility.

For the Mount Hope Bay estuary, nonpoint sources were not major contributors for most of the pollutants assessed, although they did contribute some proportion of the total load for all pollutants assessed. Within the subwatershed area of the Mount Hope Bay estuary nonpoint source pollution input was minor for nutrients, and most significant for metals. The input of nonpoint source derived nutrients may be greater in the Taunton River watershed, where runoff from agricultural lands would be more prominent. Nonpoint runoff input of fecal coliform bacteria to the estuary, although unable to be assessed here, can often be significant, enough so to deteriorate water quality.

The control and management of nonpoint sources of pollution within the Taunton River and Mount Hope Bay watersheds will result in a reduction of pollutants to groundwater, rivers, streams, coves, and bays. Potential reduction of pollutant input will be greatest for metals and least for nutrients. Neither metals nor nutrients are presently perceived as problematic in the Mount Hope Bay estuary, however, federal mandates dictate that nonpoint source management will occur in the near future, and the control measures implemented by the states of Massachusetts and Rhode Island will reduce the overall input of pollutants to the bay.

In developing the nonpoint source control plan for the Mount Hope bay watershed, and for the Taunton River watershed, the planning process should focus control on a watershed basis. When more practical, the total watershed region should be broken down into subwatershed components.

WATER QUALITY CLASSIFICATION IN THE MOUNT HOPE BAY ESTUARY: A COMPARISON OF MASSACHUSETTS AND RHODE ISLAND CLASSIFICATIONS, CRITERIA, AND MANAGEMENT STRATEGIES

The classification of state waters is used both to designate the existing condition, or quality, of a parcel of water, and to designate the goal which is to be achieved with regard to water condition/quality. The goal to be achieved designates the uses that may take place in the parcel of water, as well as dictating the management strategies employed in achieving the goal. It is the goal of all state water resource management agencies to achieve fishable/swimmable water quality in all state waters, according to mandates of the Federal Clean Water Act of 1972. Fishable/swimmable waters are typically those with a designation of Class SB quality, with no limitations on its present use potential.

Both states that manage water quality in the Mount Hope Bay estuary, Massachusetts and Rhode Island, classify water quality according to the goal they wish to achieve in the bay. Management strategy, as well as use of the resource, is dictated by this classification scheme. The classification scheme, however, often results in waters that are not achieving their classification with no use(s) impaired at the present time. For example, both states have potions of Mount Hope Bay classified as SA, but use for shellfishing is impaired by not meeting designated criteria for fecal coliform concentrations. Bodies of water not presently achieving their water quality classification are termed "nonconforming." The goal, and hence management strategies, are to improve nonconforming bodies of water to meet their classified water quality condition with no uses impaired.

Since the Mount Hope Bay portion of the estuary is under interstate jurisdiction, it is necessary to determine if both states perceive similar conditions, as well as having similar management schemes for this shared body of water. In order to do this, the two states' water quality classification schemes are compared, with differences and similarities noted. Differences between state classification schemes, if any, are then considered to determine if the differences could result in conflicting use, goals, or management strategies and/or objectives.

Resource Use According to Classification

Table A provides a comparison of *uses*, according to water quality designation, for Massachusetts and Rhode Island. The comparison shows that use according to water quality designation are nearly identical between states. The conclusion drawn from this is that similar water quality designations across the state boundaries in the shared portion of Mount Hope Bay are not conflicting in present or intended uses, and that both states have similar management goals for similar water quality classifications.

Table 17. A comparison of resource uses according to water quality classification for the states of Massachusetts and Rhode Island.

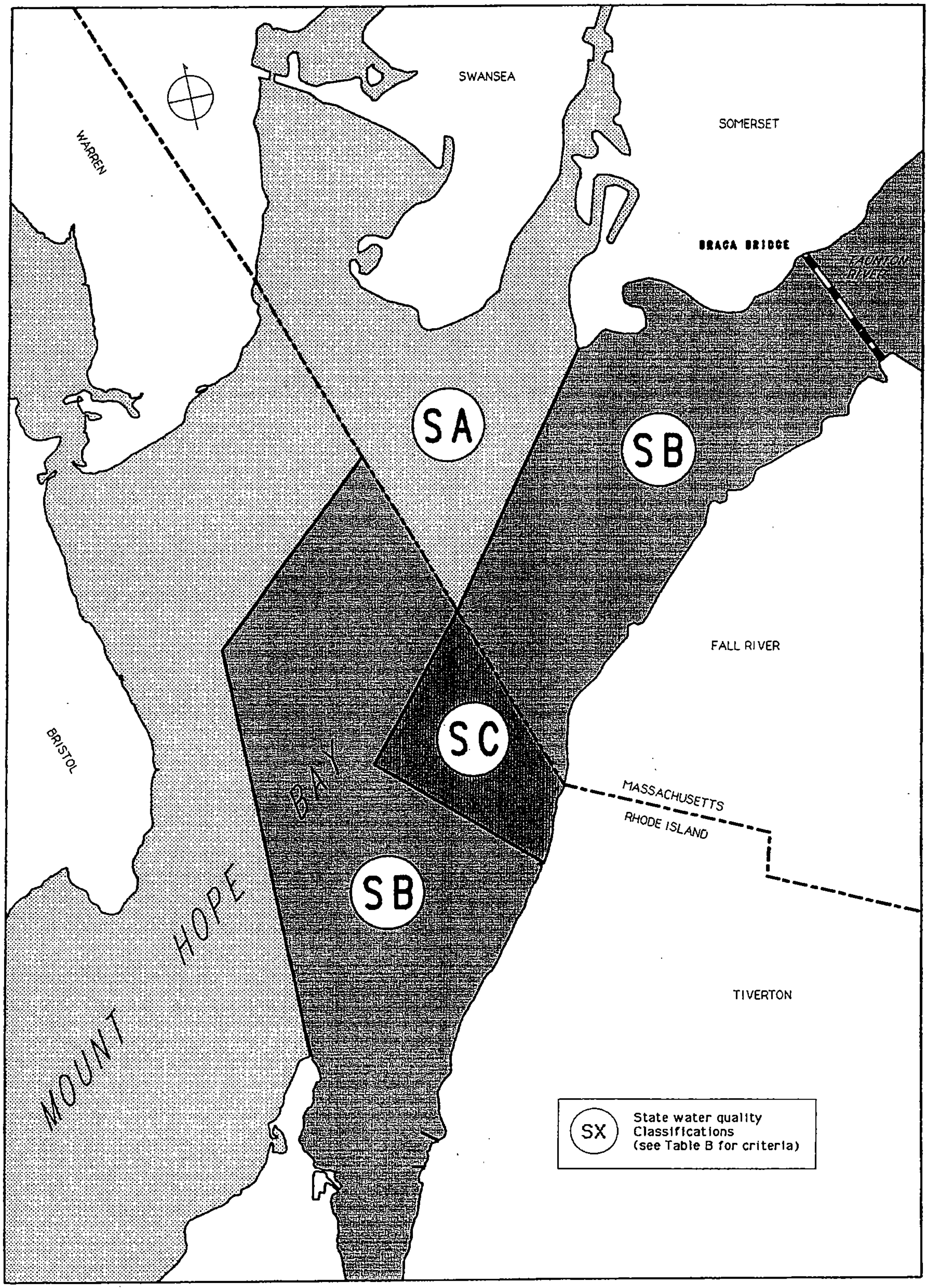
Class	Massachusetts	Rhode Island
SA	Excellent habitat for fish and wildlife, and primary and secondary contact recreation; open for shellfish harvest without depuration in approved areas; excellent aesthetic value	Bathing and contact recreation; shellfish harvesting for direct human consumption; fish and wildlife habitat
SB	Habitat for fish and wildlife and for primary and secondary recreation; shellfishing for depuration in approved areas; good aesthetic values	Shellfish harvest for depuration; bathing and other primary contact recreation; fish and wildlife habitat
SC	Habitat for fish and wildlife; secondary contact recreation; suitable for certain industrial cooling and process uses; good aesthetic value	Boating and other secondary contact recreation; fish and wildlife habitat; industrial cooling; good aesthetic values

Resource Criteria According to Classification

Table B provides a comparison of *water quality criteria* used by each state to determine water quality classification. Although a comparison of Class SC criteria is included here, it should be noted that the state of Massachusetts no longer uses the Class SC designation in classifying state waters; all marine waters receive a classification of Class SA or SB. From Table B, it can be seen that no significant differences exist between states in their water quality criteria for Class SA quality waters.

For Class SB waters, small differences exist between states for solids allowable in this class of water, with Massachusetts being more liberal than Rhode Island, but very specific to low allowable levels from discharges to receiving waters of this quality. Differences between states also exist for allowable fecal coliform levels, with Rhode Island criteria being the more stringent of the two with regard to median values, but less stringent with regard to allowable sample variability. Furthermore, Massachusetts has two Class SB fecal coliform criteria, one for shellfishing for depuration (restricted) and one for no shellfishing allowed (closed). The Massachusetts Class SB fecal coliform criteria for "closed to shellfishing" is considerably more liberal than Rhode Island fecal coliform criteria for waters of Class SB quality (200 MPN/100 ml for MA; 50 MPN/100 ml for RI), as well as for "closed to shellfishing" (>50 MPN/100 ml—RI).

The differences in fecal coliform standards presently cause a difference in water quality designation in the shared waters of Mount Hope Bay (Map 7). The Rhode Island classification for SC in the area of the Fall River STP effluent discharge denotes the restrictions to use in the effluent mixing zone of the facility. The Massachusetts classification of SB reflects the state's policy which does not allow for waters to be classified as SC (REF), but keeps the region closed



Map 7. Water quality classification for the states of Massachusetts and Rhode Island.

to shellfishing. The restriction to use in the Massachusetts Class SB (closed) section of Mount Hope Bay is similar to that of the Rhode Island Class SC designation. The Rhode Island Class SC designation, however, could potentially be more liberal with regard to new discharges than the present Massachusetts Class SB classification, potentially causing conflicting use of the bay in that region.

The Massachusetts abandonment of the Class SC designation is in response to EPA mandates for all states to meet the fishable/swimmable criteria by 1994 (?). The state of Rhode Island is presently considering a change in its water quality classification system that would abandon the Class SC designation in order to meet the same EPA mandates. Once this change

Table 18. A comparison of water quality criteria (SA, SB, SC) as used by the states of Massachusetts and Rhode Island in determining water quality conditions.

SA

Parameters	Massachusetts	Rhode Island
Dissolved Oxygen	Not <6.0 mg/1 nor <75% saturation due to discharge; site specific for background levels	Not <6.0 mg/l at any time
Temperature	Not >29.4°C nor >26.7°C daily mean; rise not >0.8°C; will not impair use; Sec 316(a) Fed Act for thermal discharge criteria	Not >28.3°C nor a rise of >0.9°C June–Sept, and not >2.2°C Oct–June
pH	6.5 - 8.5 s.u.; not >0.2 s.u. of variability	6.8 - 8.5 s.u.
Fecal Coliform	Not >14 MPN/100 ml and not >10% of samples exceed 43 MPN/100 ml for shellfishing; Not >200 MPN/100 ml and not >10% of samples exceed 400 MPN/100 ml for no shellfishing	Not >15 MPN/100 ml and not >10% of samples to exceed 50 MPN/100 ml
Solids	Not impair use or aesthetics or benthic biota or chemical composition of the bottom	None allowable that impair use
Color/Turbidity	None allowable that impair use	None allowable that impair use
Taste/Odor	None other than of natural origin	None allowable
Oil/Grease/ Chemicals	Free of oil, grease, petrochemicals	None harmful to human, animal, or aquatic life; which impairs fish/shellfish propogation; which impairs use

SB

Parameters	Massachusetts	Rhode Island
Dissolved Oxygen	Not <5.0 mg/1 nor <60% saturation due to discharge; site specific for background levels	Not <5.0 mg/1 at any time
Temperature	Not >29.4°C nor >26.7°C daily mean; rise not >0.8°C Jul–Sept nor <2.2°C Oct–June; will not impair use; Sec 316(a) Fed Act for thermal discharge criteria	Not >28.3°C nor a rise of >0.9°C June–Sept, and not >2.2°C Oct–June
pH	6.5 - 8.5 s.u. and not >0.2 s.u. of variability	6.8 - 8.5 s.u.
Fecal Coliform	Restricted shellfishing (depuration) not >88 MPN/100 ml and >10% of samples to exceed 260 MPN/100 ml; No shellfishing (closed) not >200 MPN/100 ml and not >10% of samples exceed 400 MPN/100 ml	Not >50 MPN/100 ml and not >10% of samples to exceed 500 MPN/100 ml
Solids	None that would impair use or aesthetics or chemical composition of bottom; not >25 mg/l nor >10 mg/l rise due to discharge	None allowable
Color/Turbidity	None that would impair use or aesthetics	None that would impair uses
Taste/Odor	None that would be aesthetically objectionable or impair use or flavor edible aquatic life	None that would impair uses.
Oil/Grease/ Chemicals	Free of oils, grease and petrochemical that a visible film on the water; impart oily taste to water or aquatic life; coat banks or bottom or toxic to aquatic life	None harmful to human, animal, or aquatic life; which impairs fish/shellfish propogation; which impairs use

is accomplished, it is assumed that the criteria, goals, and uses of the shared waters are identical in each of the bordering states. This however, may not be true. In order to be sure that both states are using similar criteria in judging water quality, as well as working towards obtaining the same goals, a thorough review of each state's water quality criteria, use, and goals should be conducted once the state of Rhode Island has moved into using only the Class SA and SB criteria.

This endeavor would best be completed by an Interstate Commission, which uses technical personnel from each state water resource agency as liaisons and interpreters of the water quality criteria. This will require a rather thorough review of the analytical techniques used by each state, and should result in a strict comparison of the methods used by each state

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Parameters	Massachusetts	Rhode Island
Dissolved Oxygen	Not <5.0 mg/l for16 hours of any 24 hour period; not <4.0 mg/l at any time; not <50% saturation due to discharge; site specific for background levels	Not <5.0 mg/1 for 16 hours of any 24 hour period; not <4.0 mg/l at any time
Temperature	Not >29.4°C or rise >2.8°C; will not impair use, diversity, migration, reproduction, or growth of aquatic organisms. Sec 316(a) Fed Act for thermal discharge criteria	Not >28.3°C nor a rise of >0.9°C June–Sept, and not >2.2°C Oct–June
pH	6.5 - 9.0 s.u. and not >0.5 s.u. of variability	6.5 - 8.5 s.u.
Fecal Coliform	Not >1000/100 ml for the geometic mean of samples and >10% of samples to exceed 2000/100 ml	None that impair use
Solilds	Not impair use, aesthetics, benthic biota, or chemical composition of the bottom; not >80 mg/l	None except that amount resulting from waste treatment facility providing appropriate treatment
Color/Turbidity	None that would impair use or are aesthetically objectional	None that would impair use
Taste/Odor	None that would be objectionable or impair uses or flavor edible aquatic life	None that would impair use or flavor edible fish or shellfish
Oil/Grease/ Chemicals	Free of oil, grease, petrochemicals that give oily film or oily taste to aquatic life, coats the banks or bottom, or are toxic to aquatic life	None harmful to human, animal, or aquatic life; which impairs fish/shellfish propogation; which impairs use

in determining water quality criteria. The comparison should be used to determine the compatibility of interstate data sets, and to ensure that each state is measuring the same water quality parameter to similar, if not identical, analytical levels.

The Interstate Commission should then work with the appropriate personnel at each of the state water resource agencies to arrive at analytical protocols, as well as analytical procedures, that both state agencies are willing to adopt (if different than that presently in use) and use as standards. As new criteria for water quality and related parameters are promulgated by federal agencies and authorities, it should be the duty of the Interstate Commission to ensure that each state is interpreting and implementing new regulations in a similar fashion, and in a way that maintains the standardization of methods and criteria for the shared bodies of waters between the two states.

Furthermore, the state of Rhode Island, while formulating its new water quality classification system, should reference the Massachusetts system presently in use, and make every attempt to develop a system that presents minimum conflict between states for use, goals, and criteria of the water and resources in the shared waters of Mount Hope Bay. Any residual conflicts between state water quality classification systems will need to be addressed and resolved by the Interstate Commission.

RECOMMENDATIONS FOR RESEARCH AND MONITORING INITIATIVES

Overall, very little comprehensive research has been conducted in the Mount Hope Bay estuary. Several long–term data sets exist, but they have not been fully analyzed to determine trends, or relationships with other environmental variables. Although the Narragansett Bay Project initiated a wide variety of research projects, the focus of those projects was Narragansett Bay, with Mount Hope Bay being explored only peripherally. Clearly, in order to better understand the present condition of the bay with regard to water and habitat quality, further research needs to be conducted within the estuary and riverine watershed. The following presents a summary of recommended research initiatives that will assist in building the baseline dataset needed to better understand the ecology and physics of the estuary. These research initiatives should be reviewed by the **Interstate Committee**, and funding sought to implement the studies on a continual and timely basis.

1. Marine Research Inc., environmental monitoring contractors to New England Power Co. at Brayton Point, should review their existing long–term data sets collected over their 20 years of monitoring water and habitat quality in the Mount Hope Bay estuary. The data should be statistically explored to determine the existence of long–term trends in water quality and living resources data sets. The data should be statistically explored to determine if the effluent discharge of the Brayton Point facility is effecting the concentration of dissolved oxygen in the western portion of Mount Hope Bay, and if changes in effluent temperature is responsible for the observed long–term decrease in water temperature of the bay, and to explore the potential improvement to dissolved oxygen content of bay waters by manipulating effluent temperature, should the effluent be found to effect dissolved oxygen conditions of the bay.
   Marine Research Inc. should add the collection of nutrients, phytoplankton, and zooplankton to their monitored parameters. These parameters were dropped from the monitoring routine between 1984 and 1986. The reinitialization of the collection of these parameters may help quantify the effect of nutrient inputs to the estuary upon living resources, and to help determine if nutrients are of immediate or future concern with regard to the health and viability of the estuary.

2. MADEP and RIDEM should co–sponsor a study to determine the flushing and circulation patterns of the Mount Hope Bay estuary. A major focus of this study should be to determine if circulation and flushing is reduced in the western portion of Mount Hope Bay where low dissolved oxygen bottom waters are typically formed, and to determine a baseline flow of water from the Taunton River that is required to keep a healthy turnover of water in the Mount Hope Bay estuary. The results of this study should be used to arrive at a flow figure for the Taunton River that can be used for assessment of water diversion projects in the riverine watershed.

3. MADEP should undertake, or sponsor, a routine monitoring program in the Taunton River. Sampling should occur at least at the head of tide in the river, but should include several monitoring stations in the freshwater portion of

the river. Routine parameters should include temperature, BOD-5, nutrients, and bacteria. Metals should be sampled on an occasional basis. The monitoring program may be carried out under the auspices of MADEP by coordinating with the Taunton River Watershed Alliance, a monitoring group presently performing water quality sampling in the watershed of the river.

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