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A Review of the Major Research Studies on Petroleum Hydrocarbons & Polycyclic Aromatic Hydrocarbons in Narragansett Bay 235 pp

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The Narragansett Bay Project

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FOREWORD

The United States Congress created the National Estuary Program in 1984, citing its concern for the "health and ecological integrity" of the nation's estuaries and estuarine resources. Narragansett Bay was selected for inclusion in the National Estuary Program in 1984 and designated an "estuary of national significance" in 1988. The Narragansett Bay Project (NBP) was established in 1985. Under the joint sponsorship of the U.S. Environmental Protection Agency and the Rhode Island Department of Environmental Management, the NBP's mandate is to direct a five-year program of research and planning focussed on managing Narragansett Bay and its resources for future generations. The NBP will develop a comprehensive management plan by December, 1990, which will recommend actions to improve and protect the Bay and its natural resources.

The NBP has established the following seven priority issues for Narragansett Bay:

- management of fisheries
- nutrients and potential for eutrophication
- impacts of toxic contaminants
- health and abundance of living resources
- health risk to consumers of contaminated seafood
- land-based impacts on water quality
- recreational uses

The NBP is taking an ecosystem/watershed approach to address these problems and has funded research that will help to improve our understanding of various aspects of these priority problems. The Project is also working to expand and coordinate existing programs among state agencies, governmental institutions, and academic researchers in order to apply research findings to the practical needs of managing the Bay and improving the environmental quality of its watershed.

This report represents the technical results of an investigation performed for the Narragansett Bay Project. The information in this document has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement #CX812680 to the Rhode Island Department of Environmental Management. It has been subject to the Agency's and the Narragansett Bay Project's peer and administrative review and has been accepted for publication as a technical report by the Management Committee of the Narragansett Bay Project. The results and conclusions contained herein are those of the author(s), and do not necessarily represent the views or recommendations of the NBP. Final recommendations for management actions will be based upon the results of this and other investigations.

This report is an interim report and should not be considered a comprehensive synthesis of the existing data on this subject. The interested reader is encouraged to investigate additional sources of information.

SUMMARY

This review summarizes and evaluates the available literature on petroleum hydrocarbons (PHCs) and polycyclic aromatic hydrocarbons (PAHs) in Narragansett Bay. Many of the references selected for inclusion in this summary are based on research conducted over the past 20 years in the Organic Geochemistry Laboratory of the Graduate School of Oceanography, University of Rhode Island. In general, this work has been concerned with studies on the sources, inputs, transport and biogeochemical fate of PHCs and PAHs in the bay. It is one of the largest data sets on hydrocarbons for a single estuary, and it has resulted in over 40 journal articles, reports and theses published from 1971 to 1988.

Inputs of hydrocarbons to the bay include contributions from rivers, point sources, urban runoff, combined sewer overflows (CSOs), direct industrial discharges, oil disposal practices, spills, and atmospheric deposition. The hydrocarbons transported by rivers originate from a variety of similar discharges to the rivers (e.g. point sources, runoff, CSOs, etc.).

Based on a 1985-86 study of the five major rivers discharging to the bay, the Blackstone River was the largest source of PHCs, accounting for 57% of total river input. The Taunton River was the largest contributor of PAHs (65%), but the Blackstone River accounted for 23% of the total river contribution of these hydrocarbons.

Of the 11 different point sources (10 of which were municipal treatment plants) discharging directly to the bay, the 1985-86 study showed that the Fields Point treatment plant in Providence was the largest single source of hydrocarbons, accounting for 57% of the PHCs

and 53% of the PAHs from these sources. The estimate for the amount of PHCs discharged from this plant amounted to 95 ± 63 tons (metric)/yr and was somewhat lower than previous estimates made in 1974-75 (226 ± 105 tons/yr) and in 1981-82 (258 ± 119 tons/yr). This apparent reduction in PHC input may be due to improved treatment efficiency of the plant and/or a possible reduction in the amount of PHCs entering the plant.

A comparison of river and point source hydrocarbons entering the bay during the 1985-86 study showed that point sources were the largest contributor of PHCs (70% of total) and that rivers discharged the most PAHs (90% of total).

During the period 1980-84, the total amount of PHCs discharged from all sources to the Narragansett Bay basin was estimated (±25%) to be about 1700 (range of 1300 to 2100) tons/yr, and the total amount of PAHs was estimated to be about 5.5 tons/yr. The major sources for PHCs were urban runoff (48%) and municipal treatment plants (36%). These plants were the largest source of low molecular weight PAHs (47%) and urban runoff was the biggest contribution of high molecular weight PAHs (44%) including phenanthrene, fluoranthene and pyrene.

Most of the hydrocarbons entered Narragansett Bay from the Providence River at the northern end of the bay because of the high discharges to this river from point sources, other rivers, urban runoff, spills and CSOs. The majority of the hydrocarbons (usually 90% or greater) in the water column were associated with suspended material due to the large input of particulate hydrocarbons from the various sources. The values ranged from a high of several hundred ug/l in surface waters from the upper part of the Providence River to a low of 2 to 3 ug/l in surface waters from the lower west passage. The corresponding PAH values were about 100 ng/l to 5 ng/l, respectively. This distribution resulted from the various transport processes operating in the bay and included: the mixing of fresh water and seawater at the head of the bay, the general circulation of water in the bay, and the sedimentation of particulate hydrocarbons to the bottom sediments. There was not a large difference in concentration between surface and bottom waters, based on several samples from four stations in the Providence River and upper bay.

Sediments from the Providence River to Rhode Island Sound have been analyzed for hydrocarbons by a large number of investigators. The concentration of PHCs in surface (top 2.5 to 10 cm) sediments decreased from a high of about 5,000 ug/g (dry weight) in the Providence River to a low of approxiamtely 50 ug/g in Rhode Island Sound. The corresponding values for PAHs were 20 ug/g in the river to 0.1 ug/g in the sound; and the major components in all samples were usually phenanthrene, fluoranthene and pyrene. When plotted vs distance from the river, the values showed an exponential decrease in concentration. Using this data, the half distances (log 2/slope) were calculated to be 6.4 km for PHCs and 7.2 km for PAHs. These values suggested that both types of hydrocarbons had a common source to the bay (namely the various inputs into the Providence River), and were transported down bay by similar processes (association with suspended material in the water column).

Sediment cores have been analyzed for PHCs and PAHs, and both generally showed the same trend: higher concentrations at the surface and decreasing values with depth. Once sequestered in the sediments, these components are quite stable and persist for long periods of time. The depth at which the values reach background concentrations is probably related to the time of increased petroleum utilization starting about 1880-1900; these depths varied between 20 to 50 cm depending on the sedimentation rate for different areas of the bay. A few locations in the bay showed unusual features such as a subsurface maximum at 15-25 cm depth in sediments from several stations in the east passage. Also, surface sediments from the dredged basin off Davisville, in the mid-bay area, showed very high values for both PHCs and PAHs, for that part of the bay.

Workers have estimated the accumulation of PHCs in the sediments to be about 20 to 60% of the input to the bay, and that 400-1000 tons/yr of PHCs are presently accumulating in the sediments. Using this estimate, it was calculated that about 700 to 4400 tons/yr of PHCs are entering the bay - a value that brackets the range of 1300 to 2100 tons/yr discussed earlier.

Data on the analysis of hydrocarbons in organisms is very limited; however, values for shellfish from the bay have been reported by several workers. In general, the levels for PHCs in the hard shell clam (*Mercenaria mercenaria*) were highest from the Providence River and, like the water column and sediments, decreased with increasing distance away from the river.

In the case of the Providence River samples, the PHC values appear to have increased in 1973-76 relative to samples collected in 1970-71; however, values for samples from Wickford and Dutch Island did not show any significant change during this time. In related work, a study of the persistence of chronically accumulated PHCs in clams showed that these hydrocarbons are strongly retained by the organisms and only very slowly depurated.

Samples of the soft shell clam *Mya arenaria* from Allen Harbor had high levels of PHCs and very high values of PAHs (especially phenanthrene, fluoranthene and pyrene), relative to samples of *Mercenaria mercenaria* collected from lower bay stations. Values for PAHs in the mussel *Mytilus edulis* from the lower bay have also been reported and are intermediate in concentration between *Mercenaria mercenaria* and *Mya arenaria*.

Since there are no current guidelines for safe levels of PHCs or PAHs in edible shellfish, the potential health hazards to the public are unknown at this time. However, it is clear that hydrocarbons entering the bay from a variety of sources in the Providence River and other areas can be transported throughout the waters of the bay and accumulate in the underlying sediments. There is also strong evidence that these hydrocarbons can be taken up by shellfish in amounts related to the level of sediment contamination.

There are several areas of concern where the data is either missing or inadequate to properly evaluate the impact on Narragansett Bay. One of these is the input of hydrocarbons and other pollutants into the bay from rivers, municipal treatment plants and CSOs under wet weather conditions. However, this topic is currently being investigated with funds from the Narragansett Bay Project (NBP). In a related area, the NBP is also supporting a study of pollutants in suspended material from throughout the bay in order to provide more information on the transport and deposition of these components in the estuary. Two other areas of potential importance that require additional research are the contribution of atmospheric pollutants as well as the level of organic contaminants in edible fish (e.g. flounder) from the bay. Both of these studies would provide valuable data on the impact of hydrocarbons on Narragansett Bay.

TABLE OF CONTENTS

I. INTRODUCTION

The study of petroleum (oil) in the marine environment has been a very active area of research since the late 1960s, and a wealth of information has been written on this subject. In 1975, the National Academy of Sciences (NAS) published a book entitled, "Petroleum in the Marine Environment," that was based on a 1973 workshop which considered all aspects of petroleum pollution in the oceans. About ten years later, a second workshop was held that produced another publication on this topic, "Oil in the Sea: Inputs, Fates and Effects," (NAS, 1985). The latter book provides an excellent background and summary of research up to the mid 80's on all important areas of study including: chemical composition of petroleum hydrocarbons, inputs of petroleum to the sea, biological and chemical methods of studying petroleum, and the fates and effects of petroleum in the marine environment. It is highly recommended for anyone who wishes to obtain general to specialized information concerning this topic.

The intent of this present review is to summarize the work on petroleum hydrocarbons, and polycyclic aromatic hyudrocarbons (PAHs) in Narragansett Bay. The PAHs are a class of hydrocarbons that are found in petroleum as well as produced by the incomplete combustion of fossil fuels (e.g. petroleum and coal) and wood. At the present time, it is not possible with certainty to identify those parent PAHs coming directly from petroleum as opposed to those coming from the various combustion processes. However, the 3 most abundant PAHs (fluoranthene, phenanthrene, and pyrene) found in many samples are probably derived mostly from these processes, and they have been reported in used crankcase oils, atmospheric particulates, street dust and urban runoff, as well as in estuarine waters and sediments.

The minimum requirements for selection of research for inclusion in this review are: 1) the chemical analyses of hydrocarbons must include a separation procedure (e.g. column chromatography and/or thin-layer chromatography) in order to remove non-hydrocarbon lipoidal material (e.g. fatty acids, fatty alcohols, sterols, wax esters, elemental sulfur), from the extract, and 2) the separated hydrocarbons must be analyzed by gas chromatography (GC) using a conventional detector (e.g. FID) or mass spectrometer (MS) in order to provide information on the qualitative and/or quantitative distribution of hydrocarbons. If the sample extract is not subjected to the separation procedure, non-hydrocarbon material can interfer with the weighing of hydrocarbons and/or the identification of specific hydrocarbon components by GC.

Based on these requirements, the great majority of references selected for this review are based on work done in the Organic Geochemistry Laboratory at the Graduate School of Oceanography, University of Rhode Island, over the past 20 years. In general, this work has been concerned with the sources, inputs, transport and biogeochemical fate of hydrocarbons in Narragansett Bay. It is one of the largest data sets on hydrocarbons for a single estuary and it represents over 40 journal articles, reports and theses published from 1971 to 1988. Some of this work has been previously cited in several reviews and publications on Narragansett Bay (Olsen and Lee, 1979; Seavey and Pratt, 1979; Olsen and Lee, 1980; Olsen et al., 1982; Capuzzo and McElroy, 1987).

II. METHODS

In general, the methods used by the Organic Geochemistry Laboratory to analyze hydrocarbons in waters, sediments and organisms involve essentially the same procedures. Water samples are filtered and the soluble hydrocarbons are isolated by extraction with an immiscible organic solvent. Particulate samples, sediments and whole organism (or specific tissue) homogenates are extracted with an organic solvent to isolate the hydrocarbon components. The extracts from all samples are separated into several fractions using column chromatography and/or thin-layer chromatography in order to isolate the hydrocarbons from other types of organic material found in the extracts. In most of the earlier work, the total hydrocarbons were isolated as one fraction and they included saturated petroleum hydrocarbons and polycyclic aromatic hydrocarbons, as well as small amounts of biogenic hydrocarbons. Later, the separation was improved to obtain two hydrocarbon fractions: the first containing the saturated petroleum hydrocarbons, and the second containing the polycyclic aromatic hydrocarbons.

The hydrocarbon fraction(s) are then routinely analyzed by GC/FID (and occasionally by GC/MS) in order to provide information on the qualitative and quantitative distribution of hydrocarbons in the sample. From these analyses, the amount of total hydrocarbons is determined and this value is taken as a measure of petroleum hydrocarbons (PHCs) because it includes only very small amounts of biogenic hydrocarbons (usually <5%). Also, 16 pollutant polycyclic aromatic hydrocarbons, PAHs, (EPA, 1982) are usually determined; however, in virtually all samples, the major compounds detected are phenanthrene, fluoranthene and pyrene.

The specific details of the methods for each study are described in the reference for that particular investigation. Over the 20 year period that these studies were conducted, many improvements in the analytical methods have taken place. For example, the introduction of fused silica glass capillary columns about 10 years ago has greatly improved the separation and identification of hydrocarbons (especially the PAHs) in various mixtures, and it has also improved the detection limits of the analyses. Nevertheless, since the bulk of the work described in this review was obtained using similar methods in the same laboratory, the results of earlier studies can generally be compared with more recent results, as will be discussed later.

Over the years, the Organic Geochemistry Laboratory has participated in a number of interlaboratory studies on the analysis of hydrocarbons in varous sample matrices, and the results of some of these studies have been published:

Sediments: Hoffman et al., 1979: Wade and Quinn, 1980.
Organisms: Farrington et al., 1973; Quinn and Wade, 1974;
Farrington et al., 1976: Boehm and Quinn, 1978.

In addition, we have prepared a detailed quality assurance report which includes information on the recovery and precision of our methods for a variety of sediment samples and urban dust from the National Bureau of Standards (Hoffman et al., 1982a). Based on all of these studies, we can summarize the major features of our analytical procedures for hydrocarbons. The accuracy of our method is measured as the percent recovery of blank samples spiked with laboratory standard mixtures of hydrocarbons at concentrations similar to the lower values that are usually detected in the samples. The recoveries are usually within ± 25% of the added amount, and in many cases the values are within ± 10% of the standard mixture. The precision of our combined procedures is measured as the relative standard deviation of multiple sample analyses and is generally 25% or better. (The precision of our laboratory procedures with standard mixtures is 5% or better; thus, much of the variation is due to the inhomogeniety of the samples). Our blank values are usually 20% or less of our lowest sample value, and our detection limits are sensitive enough to detect hydrocarbons in virtually every type of sample from Narragansett Bay (e.g. 1 ug/l or 1 ug/g dry sediment for PHCs, and 10 ng/l or 10 ng/g dry sediment for individual PAHs; sample size is usually 4-8 l and 5-10 g dry sediment).

III. RESULTS AND DISCUSSION

(Refer to Figure 1 for sampling locations)

A. Inputs of hydrocarbons to the Bay

1) Rivers

In 1985, Quinn et al. published their work on the monitoring of pollutants in the Pawtuxet River. Water samples were collected from 6 point sources and 12 river stations, under dry weather conditions, on 3 different dates between June 1983 and September 1984 (Appendix 1). The mass balances for suspended solids (SS), PHCs and PAHs are shown in Table 1 in which the sum of the major known point sources is compared to the value obtained by using the concentration at the last river station. The percent transported was obtained by dividing the latter value by the former value, x 100.

A similar study was carried out on the Blackstone River and the results were published in 1987 by Quinn et al. In this investigation, water samples were collected from 4 point sources and 9 river stations; the samples were collected under dry weather conditions on 3 different dates between July 1985 and October 1985 (Appendix 2). Table 2 shows the mass balances for SS, PHCs and PAHs as described for Table 1.

Water samples were collected from the mouths of 5 rivers discharging into the bay under dry weather conditions (Quinn et al., 1988). The samples were collected on 4 different dates between October 1985 and May 1986 (Appendix 3) and Table 3 shows the data from this study.

The only other available values for hydrocarbons in these rivers were reported for the Pawtuxet River by Jungclaus et al. (1978). These workers reported the presence of biphenyl (1 to 15 ppb)

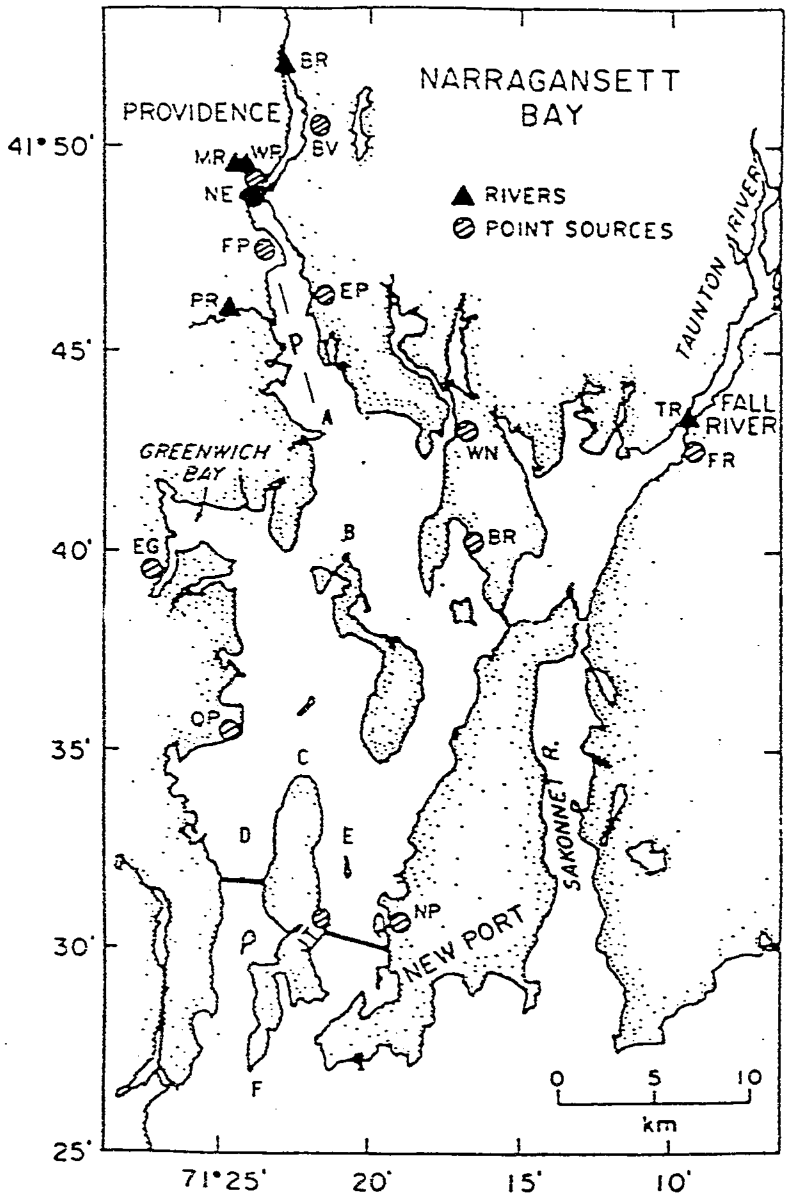


Figure 1. Sampling locations in the Narragansett Bay watershed. (From Quinn et al., 1988).

Rivers (5): Blackstone River (BR); Moshassuck River (MR); Pawtuxet River (PR); Taunton River (TR); Woonasquatucket River (WR).
Point Sources (11)-- All but Narragansett Electric are municipal treatment facilities: Blackstone Valley Plant (BV); Bristol Plant (BR); East Greenwich Plant (EG); East Providence Plant (EP); Fields Point Plant (FP); Fall River Plant (FR); Jamestown Plant (JT); Narragansett Electric Co. (NE); Newport Plant (NP); Quonset Point Plant (QP); Warren Plant (WN).

A - Conimicut Point; B - Providence Point; C - Conanicut Point; D - West Passage; E - East Passage; F - Rhode Island Sound; P - Providence River. (These are general areas of the bay and not sampling stations.)

Table 1

Mass balances for the Pawtuxet River.[a]

Component	Sum of point sources (Kg/day)	River output at last station(#11) (Kg/day)	Percent transported (%)
June 7, 1983 (flow = 1180 X 10^6 l/day)			
SS	4,250	27,400	645
PHC	176	170	97
PAH	0.067	0.036	54
August 2, 1983 (flow = 683 X 10^6 l/day)			
SS	1,860	4,740	255
PHC	37.2	47.1	127
PAH	0.015	0.062	413
September 10, 1984 (flow = 492 X 10^6 l/day)			
SS	1,780	7,760	436
PHC	48.0	51.0	106
PAH	0.131	0.270	206

SS = suspended solids;
PHC = petroleum hydrocarbons (soluble and particulate);
PAH = sum of 16 polycyclic aromatic hydrocarbons (soluble and particulate).

[a] From Quinn et al., 1985.

Table 2

Mass balances for the Blackstone River[a]

Component	Sum of point sources[b] (Kg/day)	River output at last station(#9) (Kg/day)	Percent transported (%)
July 8, 1985 (flow = 538 x 10^6 l/day)			
SS	3,640	4,510	124
PHC	152	47.0	31
PAH	0.184	0.140	76
August 20, 1985 (flow = 440 x 10^6 l/day)			
SS	3,340	2,840	85
PHC	60.0	26.0	43
PAH	0.155	0.150	97
October 8, 1985 (flow = 1010 x 10^6 l/day)			
SS	15,870	14,600	92
PHC	165	142	86
PAH	0.566	0.628	111

SS = suspended solids;
PHC = petroleum hydrocarbons (soluble and particulate);
PAH = polycyclic aromatic hydrocarbons (soluble and particulate).

[a] From Quinn et al., 1987.

[b] Includes the river itself as it enters Rhode Island from Massachusetts at the state line (station 2).

Table 3

Average values for the 1985-86 river studies[a]

Component	Pawtuxet	Moshassuck	Woonasquatucket	Blackstone	Taunton
October 21-25, 1985:					
flow ($X10^6$ l/day)	254	18.5	39.8	1,100	306
SS (KG/day)	1,710	54.3	371	4,960	5,600
PHC (Kg/day)	7.71	0.26	2.53	49.4	1.66
PAH (Kg/day)	0.103	0.005	0.022	0.302	0.370
November 18-21, 1985:					
flow (10^6 l/day)	1,550	148	265	3,780	1,540
SS (Kg/day)	12,500	607	1,280	28,900	6,160
PHC (Kg/day)	86.7	3.18	5.88	223	9.84
PAH (Kg/day)	0.395	0.021	0.037	1.76	3.10
April 7-10, 1986:					
flow ($X10^6$ l/day)	688	94.8	159	2,090	878
SS (Kg/day)	4,990	1,250	1,560	9,000	4,830
PHC (Kg/day)	46.8	17.8	22.4	76.8	21.1
PAH (Kg/day)	0.203	0.114	0.121	0.354	0.127
May 19-22, 1986:					
flow ($X10^6$ l/day)	340	75.8	62.0	824	337
SS (Kg/day)	2,000	548	485	5,680	2,060
PHC (Kg/day)	14.0	2.98	1.67	37.5	7.41
PAH (Kg/day)	0.138	0.033	0.007	0.071	0.031

SS = suspended solids;
PHC = petroleum hydrocarbons (particulate);
PAH = polycylcic aromatic hydrocarbons (particulate).

[a] From Quinn et al., 1988.

and naphthalene (6 to 10 ppb) in a few samples near the Ciba Geigy plant. Quinn et al. (1985, 1988) did not include biphenyl since it is not a priority pollutant (EPA, 1982); their values for naphthalene ranged from <0.01 to 10 ppb for lower river stations.

In the Pawtuxet River study (Table 1), the output at the last station accounted for 97 to 127% of the PHCs, and 54 to 413% of the PAHs from the sum of the point sources. The corresponding values for the Blackstone River (Table 2) were 31 to 86% for the PHCs and 76 to 111% for the PAHs. Thus, the known point sources (industrial and municipal effluents for the Pawtuxet River; and industrial, municipal and the Blackstone River itself as it enters Rhode Island from Massachusetts at station 2) account for a substantial amount of these substances in these two rivers.

Table 3 shows a comparison of the data collected for 5 rivers discharging into Narragansett Bay on four dates during 1985-86. The ranges of values for the Pawtuxet (PHC: 7.71 to 86.7 Kg/day; PAH: 0.103 to 0.395 Kg/day) are in general agreement with the values reported in Table 1(PHC: 47 to 170 Kg/day; PAH: 0.036 to 0.270 Kg/day). Similarly, the values for the Blackstone River in Table 3 generally agree with those in Table 2 (PHC: 37.5 to 223 Kg/day; PAH 0.071 to 1.76 Kg/day vs. PHC: 26 to 142 Kg/day; PAH: 0.14 to 0.63 Kg/day).

Figure 2 illustrates the average percent contribution of the 5 individual rivers (data in Table 3) to the total amount of SS, PHCs and PAHs discharged to the bay, taking into account the flow rates of the rivers over the time of the study. From these data, it is clear that the Blackstone River is the largest single source of SS (44%),

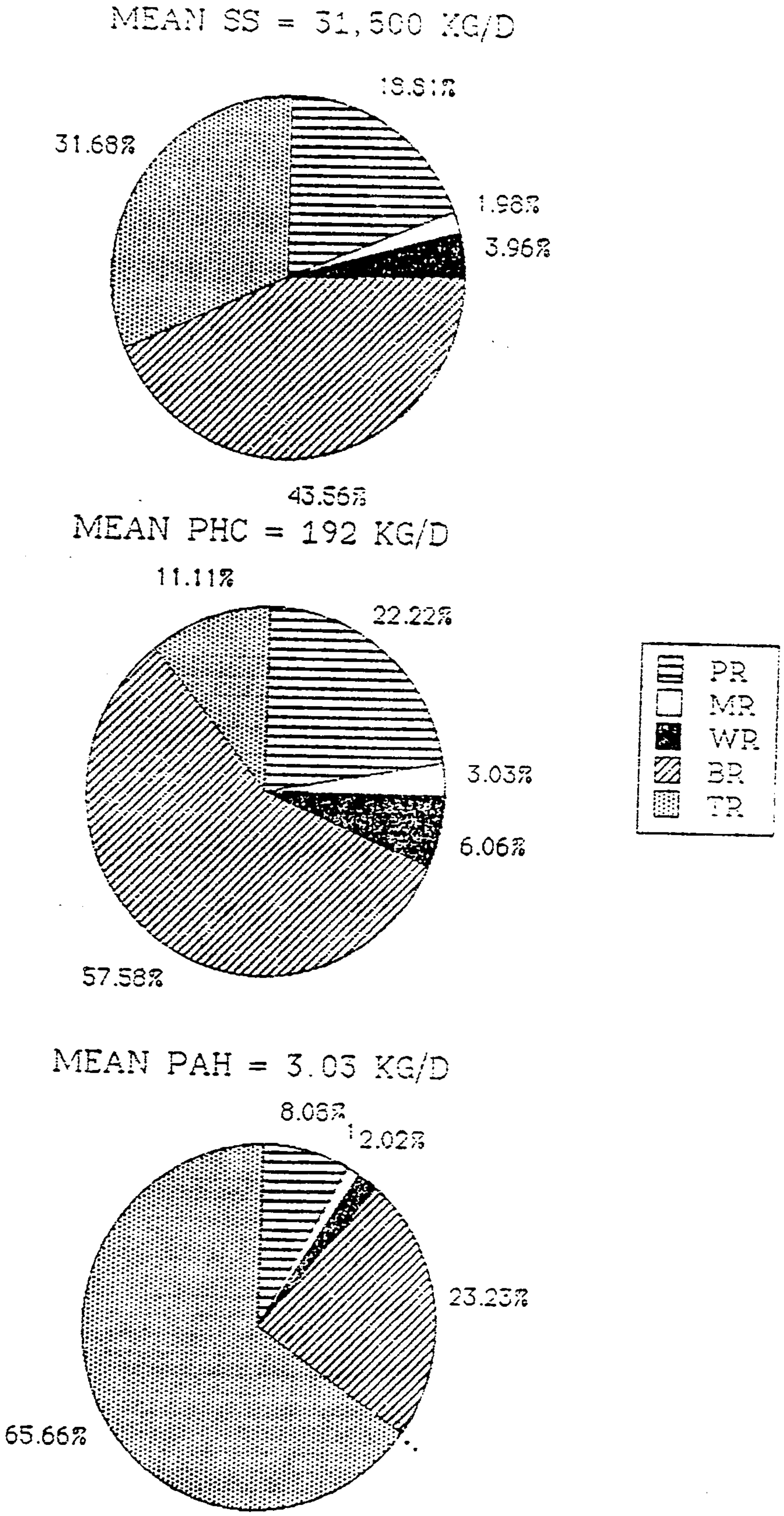


Figure 2. Percent contribution of suspended solids, particulate PHCs and particulate PAHs from rivers discharging into Narragansett Bay during 1985-86. (From Quinn et al., 1988).

PHCs (57%), and a significant source of PAHs (23%).

2) Effluents

Farrington and Quinn (1973a) reported concentrations of PHCs in sewage effluents from the Fields Point plant and East Providence plant during 1971 (Appendix 4). The values for the former plant ranged from 24 to 16.2 mg/l and averaged 7.9 mg/l for 4 grab samples. The one sample from East Providence showed 1 mg/l, and one sample from the West Warwick plant had none detected (<0.5 mg/l). The Fields Point plant was studied in more detail by Van Vleet and Quinn (1977) who analyzed 21 composite (6 days) effluent samples collected in 1974-75 (Appendix 5). They reported the following values for these samples: Soluble PHC (%): 5.3 ± 6.3: Particulate PHC (%): 94.7 ± 10.6; Total PHC (mg/l): 2.80 ± 1.31 and SS (mg/l): 45.5 ± 23.9. Using this data, they calculated that the Fields Point plant discharged about 226 ± 105 tons (metric system) of PHC into the Providence River annually.

Hoffman et al. (1984a) published their findings on hydrocarbons in sewage effluents in a report to NOAA entitled, "Hydrocarbons and other pollutants in urban runoff and combined sewer overflows" (Appendix 6). Based on a study of Fields Point during wet weather conditions in 1981-82, they reported that high concentrations of SS and PHCs were found in the effluent following very rapid changes in flow rate through the plant, presumably due to loss of large amounts of activated sludge during these wet weather periods. The particulate forms of the PHCs and PAHs become more important and some of the soluble hydrocarbon compounds in the influent became associated with particulate material during the treatment process. Calculations indicated that during rain storms of average intensity, mass discharges of SS, PHCs and high molecular weight (HMW) PAHs (3 or more rings) increased by at least 50%, increases of low MW PAHs (2 rings) were minor during these conditions. These workers also reported that 90% of the effluent PHCs were in particulate form during wet weather conditions and about 70% in dry weather. They estimated that 258 ± 119 tons of PHCs were discharged from the Fields Point plant on an annual basis (210 tons - dry weather; 48 tons wet weather). This estimate is in good agreement with that of Van Vleet and Quinn (1977) who reported a value of 226 ± 105 tons of PHC/year.

Hoffman and Quinn (1987a) compared the PHC concentrations in sewage effluents from Rhode Island (Table 4). This publication also summarized much of their work on hydrocarbons in municipal effluents in Rhode Island, and it compared this data to other treatment plants throughout the United States and Europe. The authors concluded that the PHC/SS ratio was similar among plant effluents, and that most of the PHCs were associated with particulate material; thus, effective treatment is largely dependent on removal of solids by the plants. A wide variety of petroleum products have been reported entering the various treatment plants. In the case of the Fields Point plant in Providence, industrial sources contributed the large majority of these hydrocarbons. Hoffman et al. (1984b) also estimated that about 630 tons of PHCs are discharged to the bay watershed from municipal treatment plant effluents. (There is an addition error in this calculation and the correct value is 474 tons; thus, the total amount

Table 4

Hydrocarbons in municipal wastewater [a].

Plants (secondary treatment: all in Rhode Island)	(n)	PHC conc. (mg/l)	PHC mass rate (gm HC/capita/d)	PHC/SS (mg/mg)
Providence (Fields Point)				
annual (Hoffman, et al. 1984a)	(85)	2.84	3.5	0.044
annual (Van Vleet & Quinn 1977)	(21)	2.80	3.1	0.071
winter-spring (Farrington & Quinn 1973a)	(7)	7.9	6.2	n.a.
1985-86 (Quinn et al. 1988)	(4)	1.00		0.023
West Warwick				
(Quinn et al. 1985)	(12)	3.65	1.7	0.056
(Farrington & Quinn, 1973a)	(1)	0.5	0.2	n.a.
Cranston				
(Quinn et al. 1985)	(12)	0.34	0.23	0.017
Warwick				
(Quinn et al. 1985)	(12)	0.97	0.83	0.029
East Providence				
(Farrington & Quinn, 1973a)	(1)	1.00	0.33	n.a.
REGIONAL MEAN		2.4±2.6	2.3±2.2	0.043±0.021

n.a. = not available;

[a] Adapted from Hoffman and Quinn, 1987a.

discharged should be 1580 tons/yr. However, for purposes of this review, the original value of 1730 tons/yr will be used since it is within the ±25% variation of the estimate.)

Quinn et al (1988) reported on the inputs of SS, PHCs and PAHs discharged into Narragansett Bay from 11 different point sources (10 of which are municipal treatment plants - Appendix 3). The samples were collected in 1985-86 as part of a larger study to evaluate the amount of pollutants entering Narragansett Bay from rivers and point sources during dry weather conditions, as previously discussed in the river section of this report. The four largest sources were the Fields Point treatment plant, the Blackstone Valley plant, the Fall River plant, and the Newport plant; and the data for these plants is shown in Table 5. Fields Point was the largest single source of all components on all 4 sampling dates. Figure 3 shows the average percent contribution of the 4 major plants and the combined values for the other 7 sources. The Fields Point plant accounted for 48% of the SS, 57% of the PHCs and 53% of the PAHs.

A comparison of river and point source particulate components discharging into the bay during the 1985-86 study is shown in Figure 4. Point sources are the largest contributor of PHCs (70% of total), and the rivers discharge the most PAHs (90% of total). The percentage of SS transport is 44% for the point sources and 56% for the rivers.

The calculation for PHCs discharged from Fields Point amounts to 95 ± 63 tons/yr for the 1985-86 samples compared to 226 ± 105 tons/yr (1974-75 samples) and 258 ± 119 tons/yr (1981-82 samples). Thus, it seems that there has been a significant reduction in the amount of PHCs discharged from the Fields Point plant between 1981-82

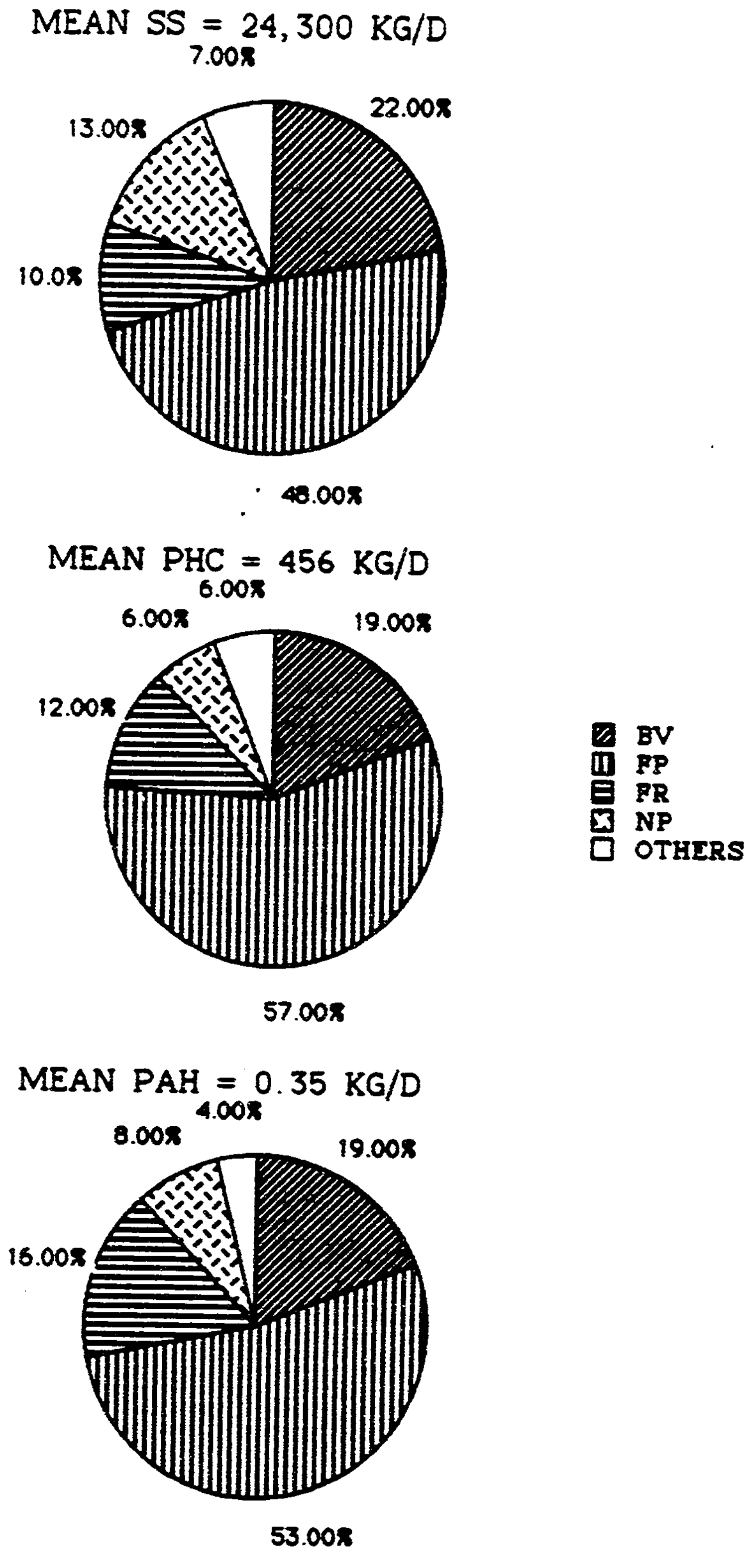
Table 5

Average values for the 1985-86 point source studies[a]

Point source	Flow (MLD)	SS (Kg/day)	PHC (Kg/day)	PAH (Kg/day)
October 21-25, 1985				
Blackstone Valley	85.6	5,720	63.9	0.106
Fields Point	196	12,100	175	0.106
Fall River	87.1	3,030	76.6	0.031
Newport	43.5	4,010	26.3	0.042
November 18-21, 1985				
Blackstone Valley	75.7	2,350	36.7	0.033
Fields Point	204	6,550	168	0.088
Fall River	96.5	1,430	32.7	0.037
Newport	32.2	1,990	14.5	0.021
April 7-10, 1986				
Blackstone Valley	87.1	3,490	40.0	0.035
Fields Point	231	6,930	182	0.218
Fall River	94.6	2,260	36.1	0.069
Newport	45.4	3,260	27.8	0.021
May 19-22, 1986				
Blackstone Valley	94.3	10,300	208	0.094
Fields Point	348	20,600	520	0.332
Fall River	85.2	2,930	78.6	0.081
Newport	26.0	3,770	42.0	0.030

SS = suspended solids;
PHC = petroleum hydrocarbons (particulate):
PAH = polycyclic aromatic hydrocarbons (particulate).

[a] From Quinn et al., 1988.



MEAN SS = 24,300 KG/D

MEAN PHC = 456 KG/D

MEAN PAH = 0.35 KG/D

Figure 3. Percent contribution of total suspended solids, total particulate PHCs and total particulate PAHs from point sources discharging into Narragansett Bay during 1985-86. (From Quinn et al., 1988).

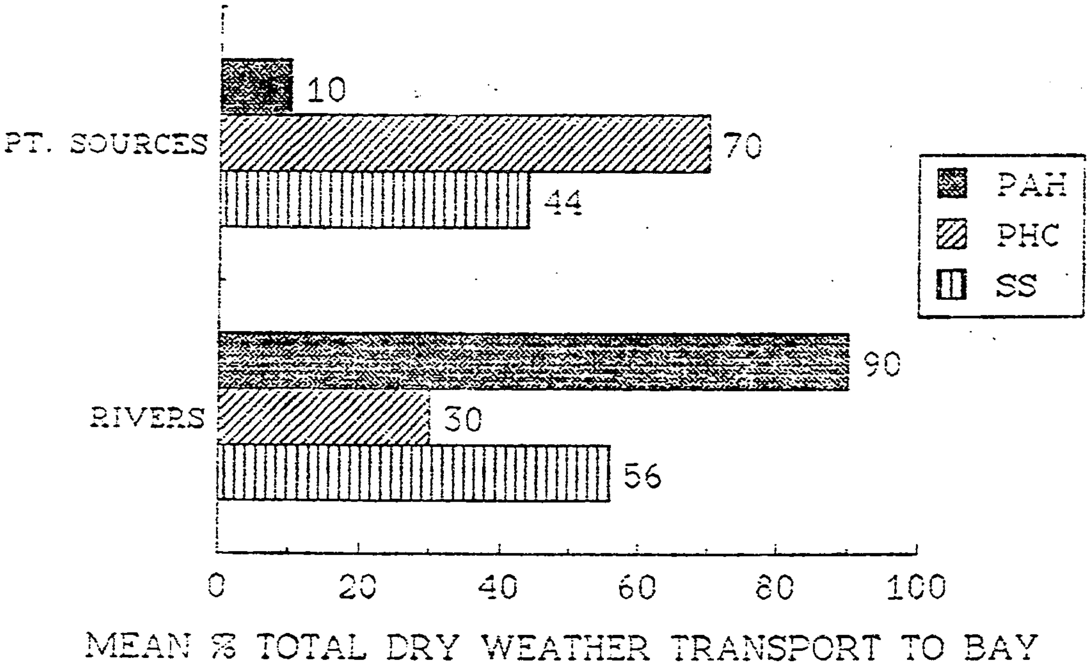


Figure 4. Comparison of river and point source particulate components discharging into Narragansett Bay during 1985-86. (From Quinn et al., 1988).

and 1985-86, this may be a result of the improved treatment efficiency of the plant due to recent repairs and upgrading, and/or a possible reduction in the amount of PHCs entering the plant. The average PHC/SS value for the Fields Point plant during the 1985-86 study (0.023 ± 0.006) was also lower than the corresponding values for 1974-75 (0.071 ± 0.039) and 1981-82 (0.044 ± 0.024) (Hoffman and Quinn, 1987a).

3) Urban runoff and combined sewer overflows

Hoffman and coworkers have published a series of papers on the input of PHCs and PAHs into Narragansett Bay from urban runoff and combined sewer overflows (CSOs). They include studies on urban runoff from commercial land use areas (Hoffman et al., 1982b) and stormwater runoff from highways (Hoffman et al., 1985): there are also reports on the input of PHCs (Hoffman et al., 1983) and PAHs (Hoffman et al., 1984c) to the coastal environment from urban runoff. In 1984, Hoffman and Quinn summarized their findings in a report to NOAA (Appendix 6): and more recently, they published a review of their work on urban runoff and CSOs (Hoffman and Quinn, 1987b). Hydrocarbon concentrations in urban runoff are a function of land use, storm hydrography and forms of precipitation. In all cases, the PHCs were largely associated with particulate (>90%) and their chemical nature was a function of storm history and/or land use (Table 6 and Figure 5). The major source of PHCs at most land use areas appears to be spilled crankcase oil on pavement surfaces, and this is also a major source of PAHS to the environment (Pruell and Quinn, 1988). CSO data on PHC are very limited and discharge rates appear to be very site specific. The Fields Point plant has been

Table 6

Annual runoff rates of PHCs and PAHs as a function of land use.[a]

	kg/km^2 drainage area/yr		
Land use	PHC	LMW-PAHs	HMW-PAHs
Residential	180	0.009	0.258
Commercial	580	0.100	0.589
Highway	7,800	1.22	16.9
Industrial	14,000	2.42	3.97

LMW = low molecule weight (2 rings);

HMW = high molecule weight (3 or more rings);

[a] Adapted from Hoffman and Quinn, 1987b.

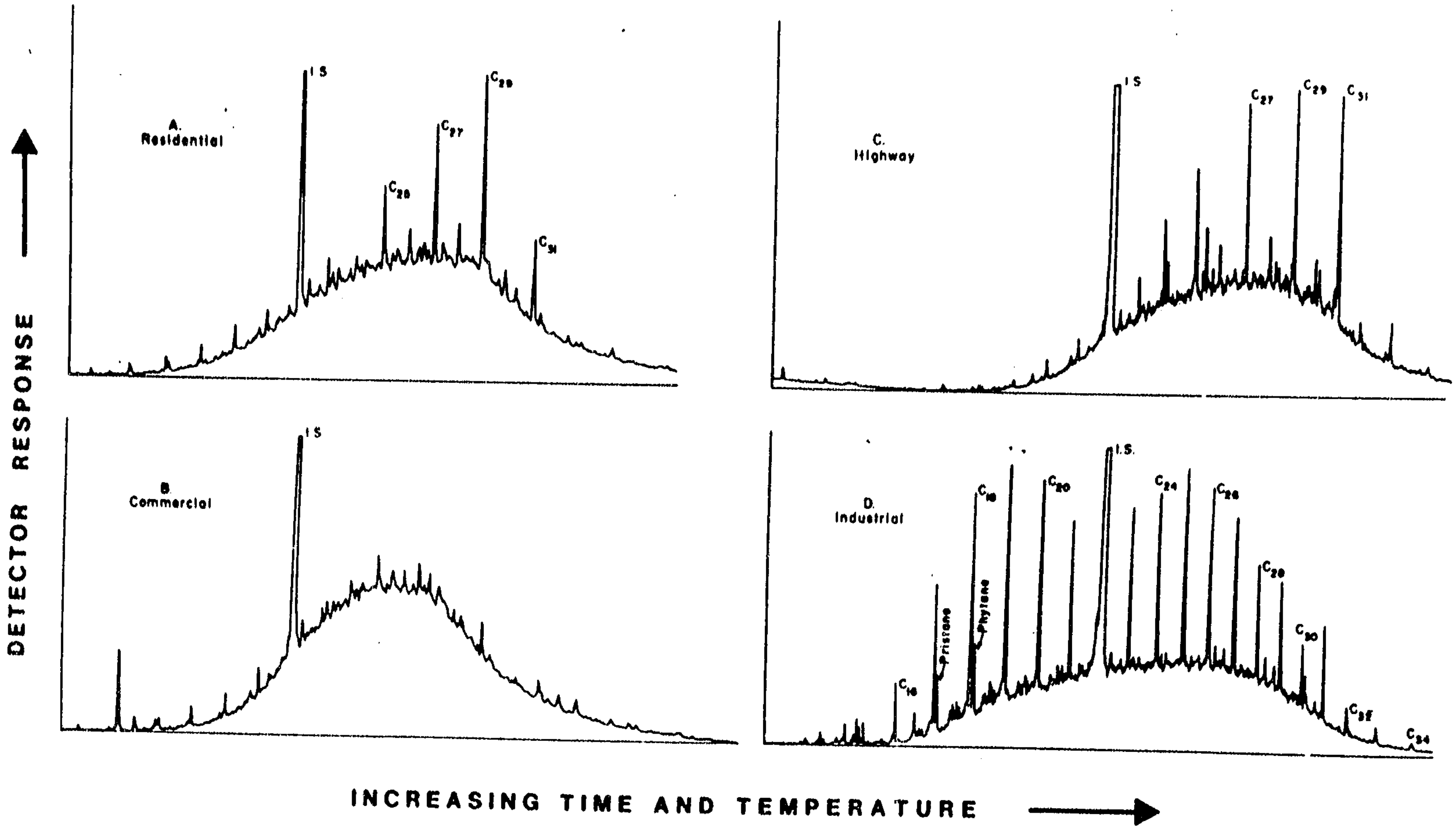


Figure 5. Gas chromatograms of urban runoff hydrocarbons at different land uses. (From Hoffman and Quinn, 1987b).

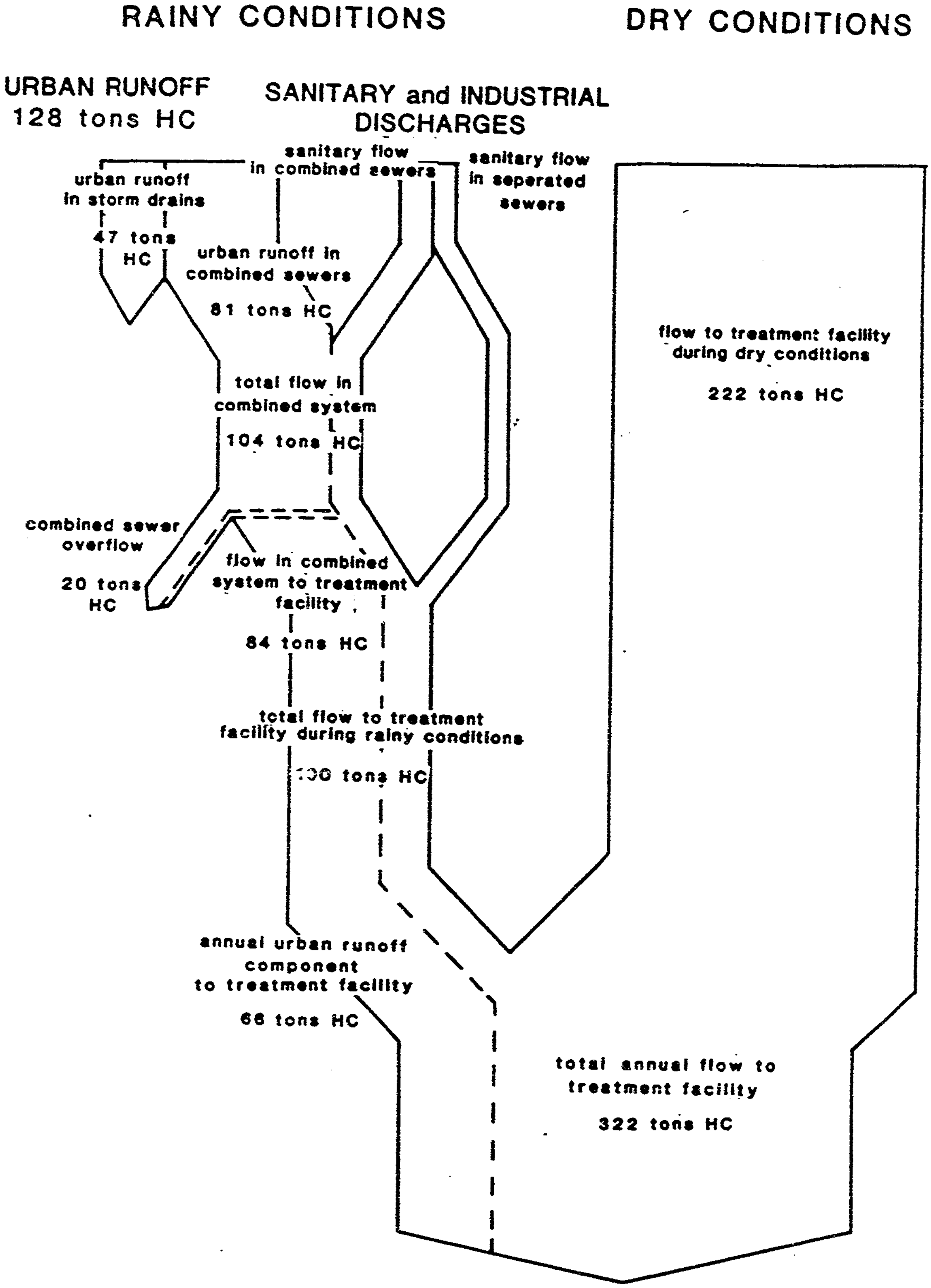


Figure 6. Estimated urban runoff and sewage pathways for PHCs in the combined and separated sewers of Providence. (From Hoffman and Quinn, 1987b).

studied in some detail and the results of this investigation are shown in Figure 6. Based on these studies, it is estimated that urban runoff can account for 832 tons/yr and CSOs can contribute 47 tons/yr of PHCs discharged to the Narragansett Bay basin (Hoffman et al. 1984b).

4) Other inputs

These inputs include direct industrial discharges, oil spills, disposal of waste lubricating oils and atmospheric deposition. Hoffman et al., 1980 reported on the disposal of waste crankcase oils based on a 1979-80 survey of Providence, Rhode Island residents. The results indicated that about 35% changed their own automotive lubricating oil and of this amount, 8% poured it down sewers or storm drains and 5% poured it on roads. This amounts to about 44 tons/yr of PHCs discharged into the Providence CSOs Extrapolating this data on a statewide basis resulted in an estimate of about 134 tons/yr discharged to Narragansett Bay from this source (Hoffman et al. 1984b).

Hoffman (1985), using federal and state data, reported on oil spills in Narragansett Bay for 1976 to 1983 and estimated that this source accounted for an average of 38 tons/yr. Hoffman et al. (1984b) also estimated the annual contribution to the bay from direct industrial discharges (47 tons/yr) and atmospheric deposition (2 tons/yr).

5) Summary of mass loadings

During the period 1980-1984, the total amount of PHCs discharged to the Narragansett Bay basin was estimated (±25%) to be about 1730 tons/yr, and the total amount of PAHs discharged was

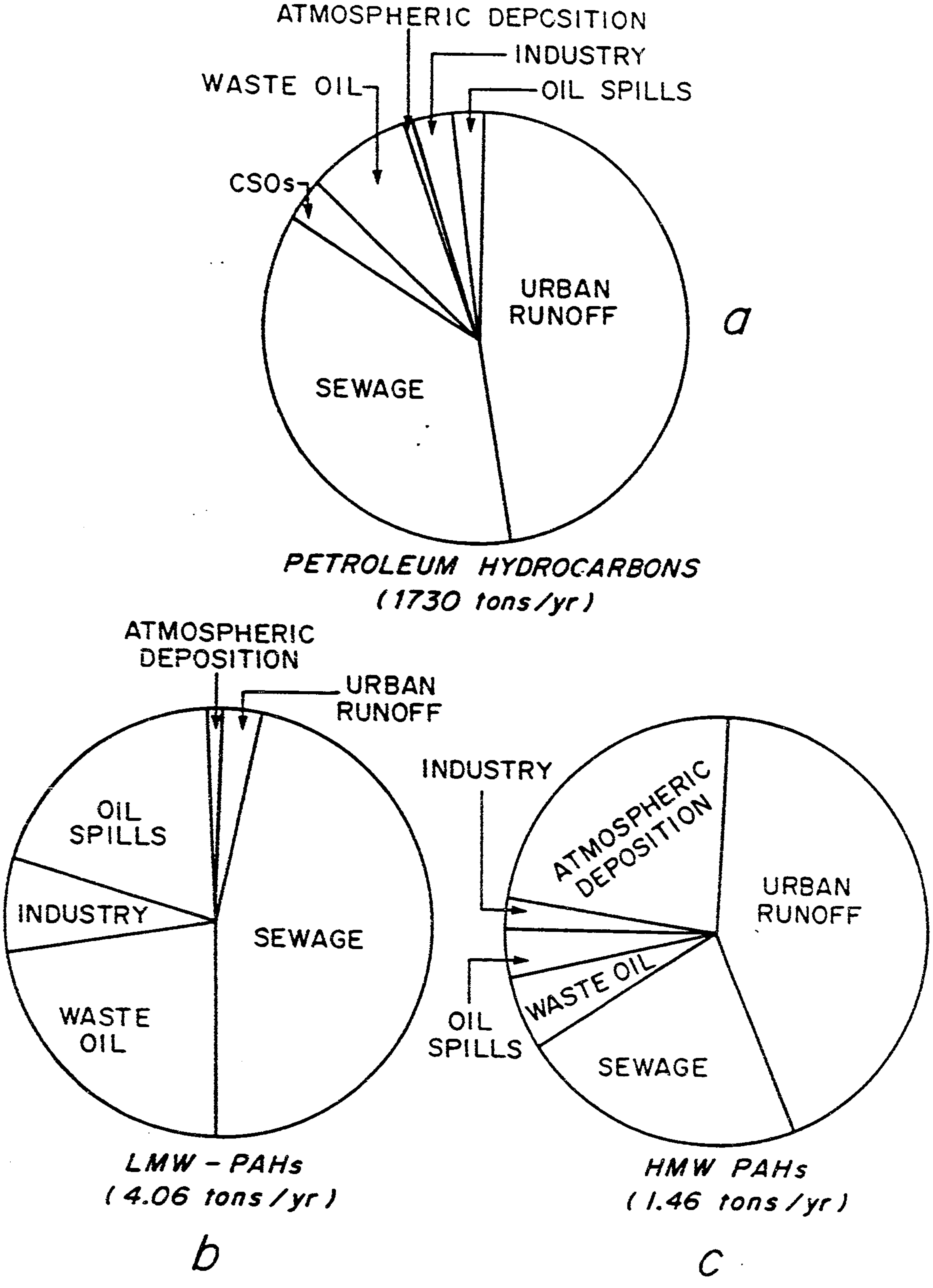
Table 7

Pathways of hydrocarbon entry to the Narragansett Bay watershed during 1980-84.[a]

Discharge	PHC Metric tons/year	LMW-PAH Metric tons/year	HMW-PAH Metric tons/year
Urban runoff	832	0.13	0.64
CSOs wet	47	nd[b]	nd
Municipal treatment plants	630	1.90	0.32
Direct industrial discharges	47	0.32	0.03
Oil spills	38	0.77	0.05
Waste oil disposal	134	0.93	0.08
Atmospheric deposition	2	0.01	0.34
Total	1,730	4.06	1.46

[a] Adapted from Hoffman et al., 1984b; and Hoffman and Quinn, 1987b;

[b] not determined.



PETROLEUM HYDROCARBONS (1730 tons/yr)

LMW - PAHs (4.06 tons/yr)

HMW PAHs (1.46 tons/yr)

Figure 7. Pathways of hydrocarbon entry to the Narragansett Bay watershed during 1980-84. (From Hoffman and Quinn, 1987b).

estimated at about 5.5 tons/yr (Hoffman et al. 1984b; Hoffman and Quinn, 1987b). The specific amounts are shown in Table 7 and illustrated in Figure 7. The hydrocarbons transported by rivers were not listed because they originate from the discharges to the rivers that are already included in the table. Clearly, the 2 major sources for PHCs are urban runoff (48%) and municipal treatment plants (36%). These plants are the largest source of LMW PAHs (47%) and urban runoff is the biggest contributor of HMW PAHs (44%).

B. Distribution of hydrocarbons in the water column of the bay

In 1977, Van Vleet and Quinn reported on the concentrations of particulate PHCs at 4 surface stations in the Providence River during flood tide (Appendix 5). They found values of 6 to 520 ug/l with the highest value at the Fields Point outfall (Table 8). They calculated that sewage effluents could account for 42-84% of the particulate PHCs in the river, and that about 50% of these hydrocarbons are deposited in the sediments of the river with the other half flushed out into the upper bay.

Shultz and Quinn (1977) studied the PHCs in particulate material from 10 surface stations in the Narragansett Bay basin during ebb tide (Appendix 7). Their average values ranged from 99.5 ± 51.1 ug/l at Fields Point and 8.0 ± 7.3 ug/l at the mouth of the Taunton River to 2.8 ± 2.3 ug/l at the Jamestown Bridge in the lower west passage of the bay (Table 8 and Figure 8). They also measured the concentration of particulate PHCs in 14 surface water samples from a west passage station between Wickford Harbor and Conanicut Point on Jamestown. The samples were collected from October 1973 to March 1974 and averaged 3.5 ± 1.7 ug/l. Duce et al. (1972) reported PHC values of 5.9 and 8.5 ug/l in unfiltered surface samples from the

Table 8

Particulate hydrocarbons in surface waters[a] from Narragansett Bay.

Location	Concentration (ug/l)	Reference
Providence River		Van Vleet & Quinn, 1977 (sample collected in 1975)
Fox Point	21	
Fields Point	520	
Gaspee Point	6	
Conimicut Point	8	
Fox Point	219	Schultz & Quinn, 1977 (samples collected in 1972-74)
Fields Point	99.5 ± 51.1	
Conimicut Point	38.5 ± 31.2	
Taunton River (mouth)	8.0 ± 7.3	
Upper Bay		
Warwick Point	16.3 ± 13.3	
Ohio Ledge	12.9	
Bristol Point	4.5 ± 2.7	
Lower Bay		
Wickford-Conanicut Point	6.9 ± 5.5	
South Prudence	2.9 ± 2.5	
Jamestown Bridge	2.8 ± 2.3	

[a] top 20 to 30 cm of water surface.

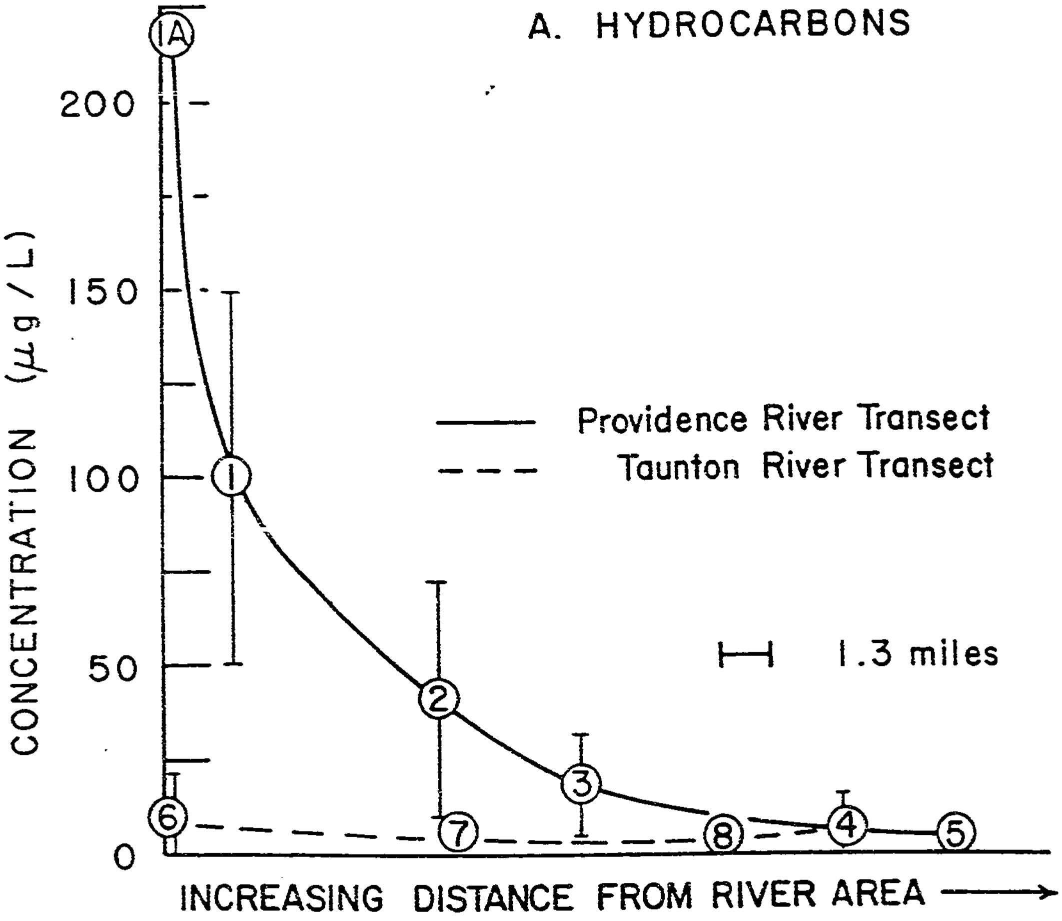


Figure 8. Average PHC concentrations in particulate material from Narragansett Bay. (From Schultz and Quinn, 1977).

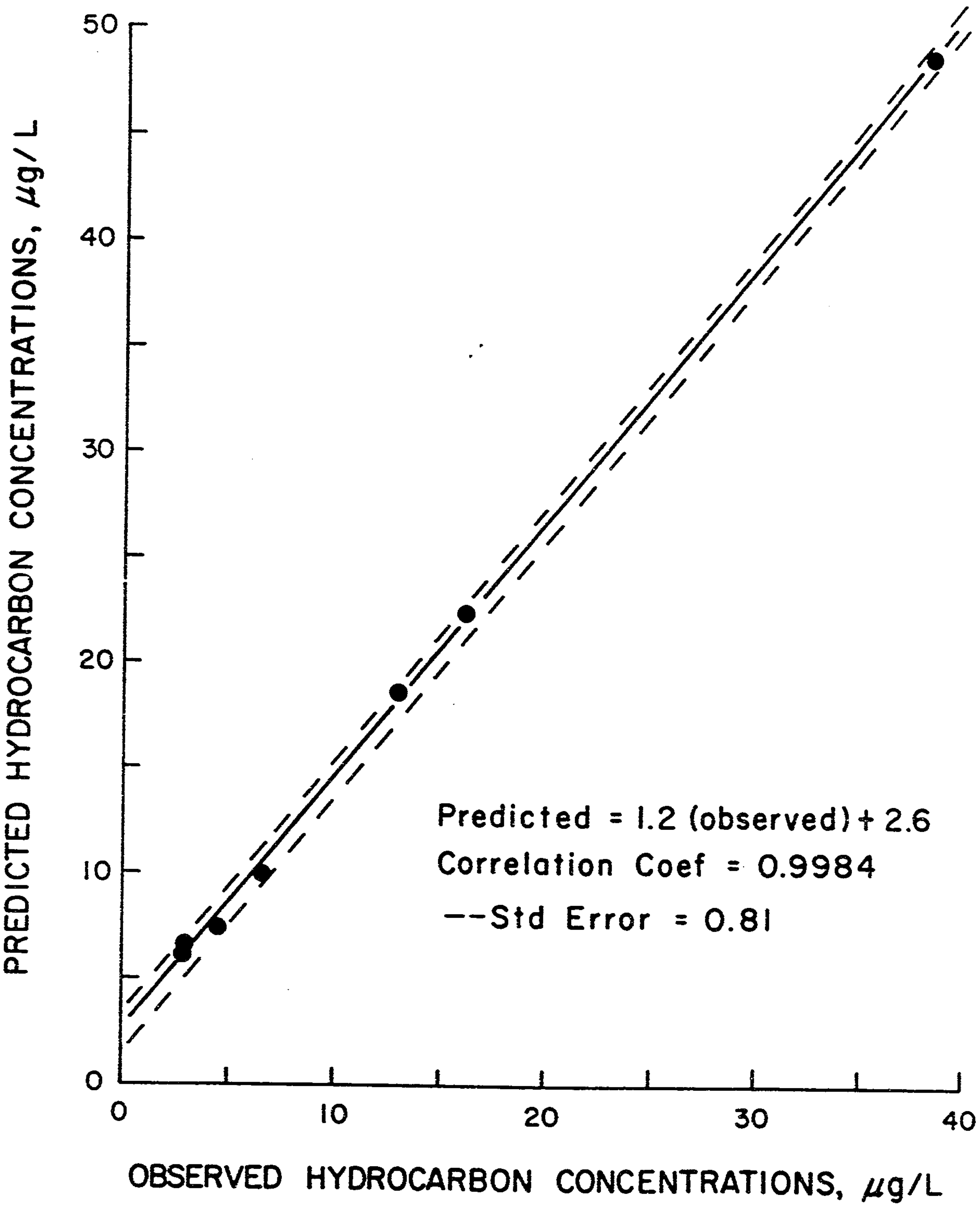


Figure 9. Predicted vs. observed PHC concentrations in particulate material from Narragansett Bay. (From Schultz and Quinn, 1977).

lower West Passage of the bay.

Using the particulate PHC concentrations values from the Fields Point station, Schultz and Quinn (1977) estimated the concentrations of PHCs at 7 other stations in Narragansett Bay using a hydrodynamic model of the bay. The results of the model and the observed PHC concentrations were in very good agreement (Figure 9), suggesting that the major source of particulate PHCs for the bay was the Providence River. This observation was later confirmed by the work of Hoffman and Quinn (1987a,b) and Quinn et al. (1988) who showed that large discharges of PHCs enter the Providence River from a variety of sources including urban runoff and municipal treatment plant effluents. The work of Schultz and Quinn (1977) also indicated that sedimentation was an important process in the transport of PHCs in the bay, since the observed concentrations averaged about 20% lower than those predicted by the model (Figure 9).

Quinn et al. (1988) reported on the concentrations of hydrocarbons from 2 stations in the Providence River and 2 stations in the mid-bay area collected four times during the 1985-86 study of the bay by the Narragansett Bay Project. Samples were collected from 3 or 4 depths at each station and analyzed for particulate PHCs and PAHs and a few samples were analyzed for soluble hydrocarbons (Appendix 3). In all cases, the levels of particulate PHCs were much greater than those of the soluble PHCs; and in most cases, the same held true for the particulate PAHs. The average concentrations of surface and bottom particulate hydrocarbons are shown in Table 9. Surface values for PHCs ranged from 13 to 26 ug/l in the Providence River to about 4 ug/l in the mid-bay areas. The corresponding values

Table 9

Concentrations of particulate components in Narragansett Bay surface water and bottom water samples^a.

	Surface			Bottom		
	SS (mg/l)	PHCs (ug/l)	PAHs (ng/l)	SS (mg/l)	PHCs (ug/l)	PAHs (ng/l)
Station 2						
mean	3.89	25.9	89.1	2.91	13.3	42.2
sd	1.94	23.4	61.7	1.02	9.35	12.7
min	2.17	10.7	38.4	1.85	6.16	24.3
max	6.57	60.1	176	4.04	26.1	53.4
Station 4						
mean	3.60	12.6	29.0	14.5	14.8	75.7
sd	1.62	6.12	10.1	14.0	10.3	62.8
min	1.89	5.16	15.8	3.42	5.71	23.3
max	5.72	19.7	40.4	33.6	28.3	166
Station 7						
mean	2.31	3.70	11.1	3.16	3.89	15.4
sd	0.31	1.33	5.37	0.56	1.85	2.03
min	2.00	1.85	5.70	2.79	2.21	12.9
max	2.73	4.70	18.0	3.99	6.33	17.1
Station 12						
mean	1.61	4.00	8.50	2.97	3.44	14.9
sd	0.30	1.83	3.74	0.79	1.10	6.13
min	1.16	2.20	3.40	2.11	2.08	4.70
max	1.84	6.53	12.3	3.66	4.75	20.5

[a] From Quinn et al., 1988.

for bottom water were 13 to 15 ug/l in the river and 3 to 4 ug/l at the mid-bay stations. Surface PAH values were 29 to 89 ng/l in the river and 9 to 11 ng/l in the mid-bay areas. The corresponding bottom water values were 42 to 76 ng/l and about 15 ng/l, respectively.

Based on the above three studies of hydrocarbons in the water column of Narragansett Bay, several general conclusions can be drawn. The major source of hydrocarbons to the bay is the Providence River (and its tributaries) with smaller inputs from the Taunton River. Most of the hydrocarbons (usually 90% of total) in the water column are associated with particulate material; this is probably due to the large inputs of particulate hydrocarbons from urban runoff, municpal treatment plant effluents, etc. Additional sources of particulate hydrocarbons include adsorption of dissolved hydrocarbons onto particles as well as resuspended sediment due to storms and/or currents. The values range from a high of several hundred ug/l in the upper part of the Providence River to a low of 2 to 3 ug/l in the lower west passage. This distribution results from the various transport processes operating in the bay and includes the mixing of fresh water and seawater, the general circulation of water in the bay, and sedimentation of particulate material and its associated hydrocarbons into the bottom sediments. There does not appear to be a large difference in concentration between surface and bottom waters, based on the 4 stations available for comparison.

C. Distribution of hydrocarbons in the sediments of the bay

(Values given on dry weight basis.)

Farrington and Quinn (1973b) conducted a survey of PHCs in surface sediments (0-10 cm) from Narragansett Bay (Appendix 4). Their values ranged from a high of 2110 ug/g at Fields Point in the

Table 10

Hydrocarbon concentrations in surface sediments from Narragansett Bay.

Location	Concentration (dry weight basis) PHCs	 PAHs
Seekonk River	2330[f]	41.9[f]
Providence River		
Fox Point	1410[b]; 9120[f]	19.8[f]
Fields Point	2110[a]; 5410[b]; 2950[f]	4.06[f]
Sabin Point	2040[a]; 3540[f]	2.14[f]; 2.1[g]
Pawtuxet Cove	4970[f]	8.04[f]
Gaspee Point	450[b]	
Bullock Point	1616[f]	1.72[f]
Conimicut Point	570[b]; 1710[f]	2.51[f]; 1.6[g]
Upper Bay		
Conimicut Point to Providence Point	710[a]; 454 to 509[c]; 666[f]	1.42[f]; 1.0[g]
Mid-bay		
Providence Point to Conanicut Point	400[a]; 112 to 505[c]; 185[d]; 124 to 414[f]; 934[i]; 142 to 148[j]; 214[k]	0.20 to 0.34[f]; 0.5[g]; 1.1[h]; 9.8[i]; 1.8 to 7.5[l]
East Passage	287[b]; 35 to 283[c]	
West Passage	110 to 150[a]; 29 to 246[c] 33[k]	
Rhode Island Sound	60[a]; 25[b]; 1 to 301[e]; 43 to 48[f]	0.12 to 0.14[f] 2.5[l]

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[a] Farrington and Quinn, 1973. Samples collected in 1970-71; top 0-10 cm.

[b] Van Vleet and Quinn, 1978. Samples collected in 1975-77; top 0-10 cm.

[c] Hurtt and Quinn, 1979; Appendix 8. Samples collected in 1976-77; top 0-5 cm.

[d] Wade and Quinn, 1979. Samples collected in 1977; top 0-5 cm.

[e] Boehm and Quinn, 1978; Appendix 9. Samples collected in 1975; top 0-10 cm.

[f] Pruell and Quinn, 1985; Appendix 10. Samples collected in 1979-80; top 0-2.5 or 5 cm.

[g] Lake et al., 1979; top 0-10 cm.

[h] Boehm et al., 1987. Samples collected in 1984-85; top 0-1 cm.

[i] Quinn et al., 1980. Samples collected in 1980; top 0-10 cm.

[j] Gearing et al., 1978. Samples collected in 1976-77; top 0-10 cm.

[k] Lake et al., 1980; top 0-10 cm.

[l] National Status and Trends Program, 1988. Samples collected in 1984-87; top 0-1 cm.

Providence River to a low of 60 ug/g in sediments from Whale Rock at the mouth of the bay (Table 10). Zafiriou (1973) also analyzed the hydrocarbons isolated from the sediments at Sabin Point in the Providence River using chemical and ^{14}C isotopic analyses. He concluded that petroleum products were the ultimate source of most of these hydrocarbons.

In 1978, Van Vleet and Quinn reported on the PHC concentration in sediment cores from 4 stations in the Providence River. The values for the surface sediments (0-10 cm) were highest at Fields Point (5410 ug/g) and decreased towards the mouth of the river (Table 10); the distribution with depth showed higher values in the surface sections which generally decreased with depth to 30-40 cm. These authors also analyzed a sediment core from the east passage of the bay and one from Rhode Island Sound and found similar trends in PHC distributions with depth in the cores.

Hurtt and Quinn (1979) analyzed PHCs in 20 sediment cores from Narragansett Bay (Apendix 8). The surface sediment (0-5 cm) values decreased from the Providence River to the mouth of the bay (Table 10); and the concentrations generally decreased with depth in the cores, usually levelling off (about 5 ug/g) at 20-25 cm depth (Figure 10). This depth probably corresponds to the time of increased petroleum utilization starting about 1880-1900. Several stations east of Prudence Island showed increased levels of PHC with depth, but the exact cause of this phenomenon could not be determined. Another station, south of Prudence Island, also showed this trend, and is in agreement with the findings of Van Vleet and Quinn (1978) for a station in the same general location. Since this site was used

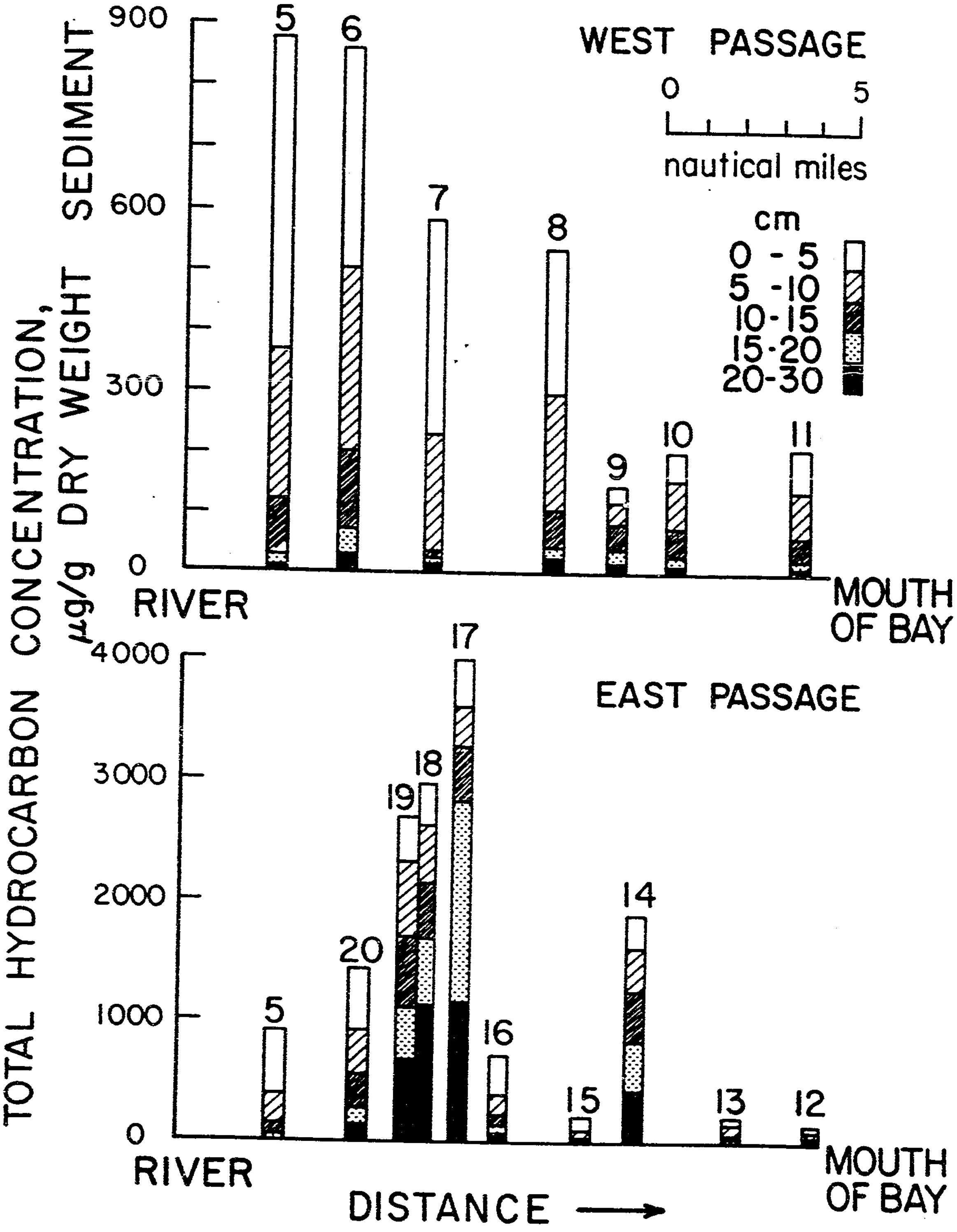

Figure 10. Concentrations of PHCs with depth in Narragansett Bay sediments. (From Hurtt and Quinn, 1979).

as a disposal area until 1965, the subsurface maximum in PHCs may be a result of hydrocarbon contaminated dredged material from harbors and coves throughout the bay.

The PHCs in sediments from Rhode Island Sound were investigated by Boehm and Quinn (1978, Appendix 9). These workers analyzed 21 surface sediments (0-10 cm) and 2 sediment cores. The concentrations for surface samples normally ranged from 1 to 56 ug/g; however, values up to 301 ug/g were observed in samples from a dredge spoil site located in the study area (Table 10). The core sample collected at this site showed values ranging from 184 ug/g at the surface to 2270 ug/g at a depth of 35-45 cm. Based on the results of the study, no effects of the dredge spoil deposit (containing 5,000 to 20,000 metric tons of PHCs) were observed beyond 2 km from the disposal site. Using the values for PHCs, polychlorinated biphenyls and pollen content in a core from outside the disposal area, the sedimentation rate was estimated to be 0.1 to 0.3 cm/yr.

Wade and Quinn (1979) studied the distribution of PHCs in a sediment core from the MERL site, north of Conanicut Point on Jamestown Island. They found a surface (0-5 cm) concentration of 185 ug/g (Table 10) decreasing to a value of 7 ug/g at a depth of 20-25 cm. From that point on, the values remained constant at 4-6 ug/g down to 35-41 cm.

Quinn et al. (1980) reported on the concentrations of PHCs and PAHs in surface sediments from the dredged basin off Davisville, and in a sediment core from Allen Harbor (Quinn and Pruell, 1980a). The PHC value for the Davisville sample were relatively high for that area of the bay, and some of the PAH values were as high as found in many sections of the Providence River (Table 10). The exact source of these hydrocarbons is unknown but they may be from previous shipping activities in this area as well as possible land based discharges.

Santschi et al. (1984) used the data of Hurtt and Quinn (1979) to estimate that the accumulation of PHCs in the sediments was 23 to 58% of the input into the bay, and that 400-1000 tons/yr of PHCs are presently accumulating in the bay sediments. Estimated net sedimentation rates ranged from 0.01 cm/yr in the lower and mid-bay sections to 0.5 cm/yr in the upper bay. The estimate of the percent of PHCs accumulating in the bay sediments agrees with the value of 50% for the Providence River by Van Vleet and Quinn (1979). A calculation of the input of PHCs gives a range of about 700 to 4400 tons/yr and brackets the estimate of 1730 tons/yr by Hoffman and Quinn (1987b). The estimated sedimentation rate in the lower bay (0.01 cm/yr) does not agree with the values (0.1 to 0.3 cm/yr) for Rhode Island source by Boehm and Quinn (1978).

Sediments from the Providence River to Rhode Island Sound were anlayzed for PHCs and PAHs by Pruell and Quinn (1985; Appendix 10). The values for surface sediments (top 2.5 to 5 cm) are shown in Table 10. These values are plotted vs. distance from station 1 (Fox Point) in Figure 11 and show an exponential decrease in concentration with distance from the river to the sound. Using this data, the half-distances (log 2/slope) were calculated to be 6.4 km for PHCs and 7.2 km for PAHs. These values are quite similar and suggest that both types of hydrocarbons have common sources to the bay, namely the various inputs into the Providence River (e.g. sewage effluents and urban runoff). The distribution of major PAHs in surface sediments

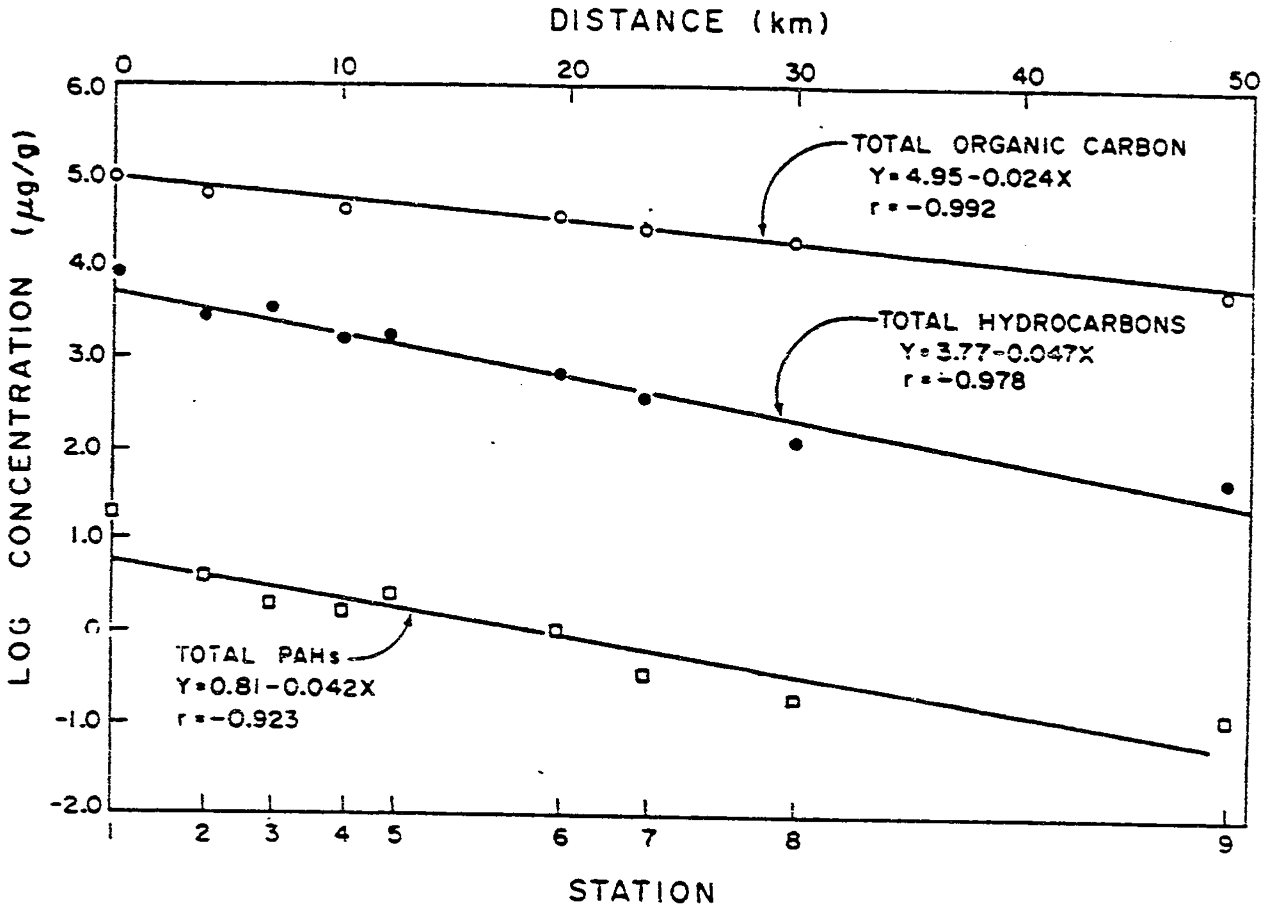

Figure 11. Semi-log plot of the surface sediment concentrations of total organic carbon, total PHCs and total PAHs on a transect from Fox Point (station 1) to Rhode Island Sound. (From Pruell and Quinn, 1985).

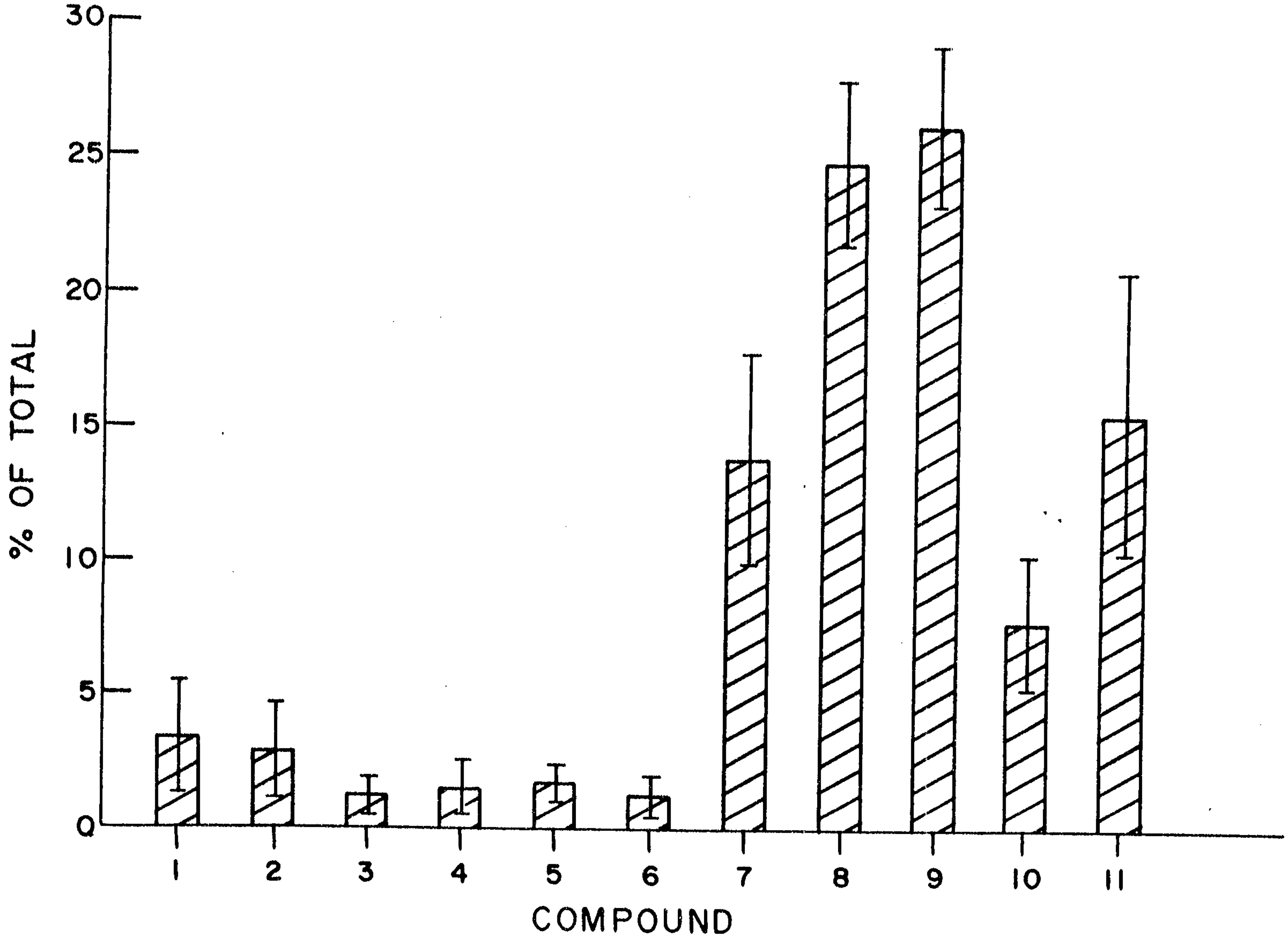

Figure 12. Relative percent distributions of PAHs in surface sediments from Narragansett Bay. Compound 1, naphthalene; 2, 2-methyl naphthalene; 3, 1-methyl naphthalene; 4, biphenyl; 5, fluorene; 6, dibenzothiophene; 7, phenanthrene; 8, fluoranthene; 9, pyrene; 10, benzo [a] anthracene; 11, chrysene + triphenylene. (From Pruell and Quinn, 1985).

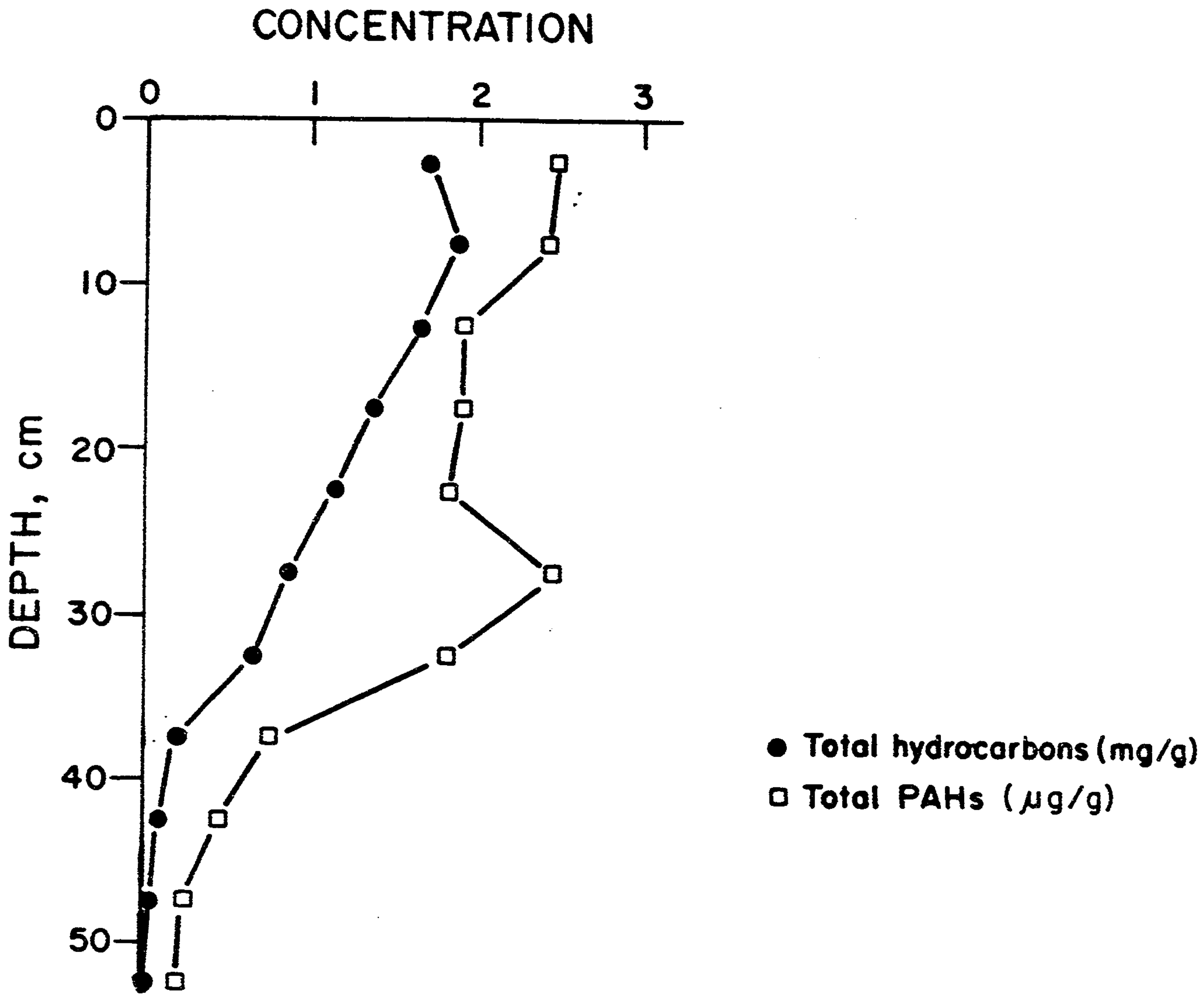

Figure 13. Depth distributions of total PHCs and total PAHs in a sediment core from Conimicut Point. The data are plotted at the midpoint of the appropriate section. (From Pruell and Quinn, 1985).

is shown in Figure 12 and illustrate that these components are dominated by the unsubstituted PAHs especially phenanthrene, fluoranthene and pyrene. There were no consistent changes in the relative distributions of these PAHs with distance downbay or with depth in the 3 sediment cores investigated during this study. This PAH distribution is also similar to those measured by Lake et al. (1979) for bay surface sediments. It is believed to result from the input of HMW combustion-derived PAHs; the major sources to the bay include urban runoff, sewage effluents and atmospheric deposition as shown in Table 7.

Three sediment cores were analyzed for hydrocarbons (Pruell and Quinn, 1985) and the results for the Conimicut Point (Providence River) sample are shown in Figure 13. The PHCs were very high in the upper few sections (5 cm each) of this core, and then decreased with depth until about 45 cm where the values levelled out. The concentrations measured in this core are higher than those measured by Van Vleet and Quinn (1977) from a nearby location. The reason for the differences may be that the earlier core was probably collected closer to the dredged channel in the Providence River. The PAHs were also highest in surface sections and generally decreased with depth to about 50 cm (Figure 13).

The hydrocarbons in the Conimicut Point core showed the expected trends with depth and all have well defined profiles. This is indicative of a location with a high sedimentation rate and a small bioturbation zone. The sedimentation rates were estimated to be about 0.8 cm/yr for both PHCs and PAHs; this value is within the range of values (0.6 to 1.8 cm/yr) calculated by Elderfield et al. 1981 which were based on the results of pore water nutrient profiles.

Two other cores were investigated by Pruell and Quinn (1985) but sedimentation rates were not calculated due to extensive bioturbation in the Conanicut Point core and possible contamination by dredge spoil material in the Rhode Island Sound core.

Other studies of hydrocarbons in sediments from Narragansett Bay include Jungclaus et al. (1978) who reported on the concentrations of a number of individual alkane and aromatic hydrocarbons from surface sediments in the Pawtuxet River and Pawtuxet cove. The major components were PAHs including phenanthrene fluoranthene and pyrene at concentrations of 0.2 to 75 ug/g. Gearing et al., 1978 analyzed surface sediment from the MERL site north of Conanicut Point and reported average PHC values of about 142 to 148 ug/g (Table 10). Juanita and Patrick Gearing have also studied the geochemistry of hydrocarbons in experimental estuarine mesocosms at the MERL facility at GSO. A summary of their published work is included in a paper by Oviatt et al. (1982).

Lake et al., 1979, analyzed PAHs in surface sediments from the Providence River to lower west passage of the bay and showed a rapid decrease in concentration with increasing distance from the river (Table 10). Sediments near tarred piers were contaminated by coal tar, used to coat the pilings. All of the other sediments showed a PAH distribution resulting from a combination of petroleum products (mostly in the upper bay) and combustion processes, with the latter being the most dominant source. The 3 major PAHs detected at all stations were phenanthrene, fluoranthene and pyrene and their values ranged from 0.3-0.8 ug/g at Sabin Point to 0.07-0.2 ug/g at a station north of Conanicut Point. The National Status and Trends Mussel

Watch Program (Boehm et al., 1987) reported the concentrations of PAHs in surface sediments from a station near Conanicut Island (Jamestown) in the bay. The mean concentration was reported as 1100 ± 200 ug/g, but there is an error in the units (P. Boehm, personal communication) and the correct value is 1100 ng/g (1.1 ug/g; Table 10). A recent report cited values of 7.5 ug/g near Dyer Island and 2.5 ug/g near Block Island (NOAA Tech. Memo, 1988).

D. Distribution of hydrocarbons in the organisms of the bay

The only data sets that could be found are for hydrocarbons in shellfish from the bay. Values are given on a wet weight basis except where noted.

Farrington and Quinn (1973b) reported on the concentrations of PHCs in tissue from the hardshell clam *Mercenaria mercenaria* from Narragansett Bay (Appendix 4). The values ranged from 14 to 16 ug/g for clams taken near Sabin Point in the Providence River to 2.9 ug/g for clams collected near the GSO (Table 11). In 1975, Farrington and Medeiros reported concentrations of 90 ug/g for clams from the same station in the Providence River. It is not clear why the samples collected in 1973 were 6 times as high as those sampled in 1970-71. The methods were somewhat different in that the 1970-71 samples were quantified by gas chromatography using an internal standard, while the 1973 samples were quantified by weighing the hydrocarbon fractions from column chromatography, after qualitative analysis by GC. However, Farrington and Quinn (1973b) showed that a Providence River clam sample analyzed by both methods gave fair agreement: 14 ug/g by GC vs. 8.2 ug/g by weighing. Also, values for clams from the west passage were in general agreement: 4.1 to 10 ug/g (1970-71) vs. 9.6 in 1973 (Table 11).

The persistence of chronically accumulated PHCs in Mercenaria mercenaria was studied by Boehm and Quinn (1977). Samples of clams were taken from Bullock Point in the Providence River in July 1976 and allowed to depurate in a clean seawater system for 4 months at the GSO. The average initial PHC level of 42 ug/g (Table 11) decreased to 29 ug/g; a decrease that became statistically significant ($P < 0.1$) only at the end of the 120 day study. The authors concluded that chronically accumulated PHCs are strongly retained by the organisms and are only very slowly depurated. Boehm and Quinn (1978) also studied the PHCs in Arctica islandica from Rhode Island Sound (Appendix 9). The values ranged from 2.6 ug/g to 6.4 ug/g (Table 11).

Quinn and Pruell (1980b) reported on the analyses of two samples of the soft shell clam, Mya arenaria from Allen Harbor. They found values of 30 to 38 ug/g for PHCs (Table 11). They also analyzed PAHs in these samples and found values of 230 to 346 ng/g with the 3 major components being phenanthrene, fluoranthene and pyrene. The values for PHCs were in general agreement with values reported in 1977 and cited in the Environmental Assessment for the Davisville Port Expansion (CRC, 1981); the values for PAHs were in agreement with 1976 values reported by FDA and also cited in the above reference.

Pruell et al., (1984) analyzed PHCs and PAHs in samples of Mercenaria mercenaria purchased at Rhode Island seafood stores. The reference site for this study was Dutch Island and the PHC values ranged from 8.0 to 12 ug/g (Table 11). Thus, the values for the Dutch Island control site ranged from 5-7 ug/g in 1976 to 8-12 ug/g

Table 11

Hydrocarbon concentrations in shellfish from Narragansett Bay[a]

Date collected	ug/g wet weight Providence River	Wickford	Dutch Island or GSO	Other	Reference
1970-1971[b]	14-16	4.1-10	2.9 (GSO)		Farrington & Quinn, 1973
1973[b]	90	9.6			Farrington & Medeiros, 1975
1976[b]	42		5.3-7.1 (DI)		Boehm & Quinn, 1977
1979[b]			8.0-12 (DI)		Pruell et al., 1984
1975[c]				2.6-6.4 R.I. Sound	Boehm & Quinn, 1978
1980[d]				30-38 Allen Harbor	Quinn & Pruell, 1980

[a] Adapted from Prueil et al., 1984;
[b] *Mercenaria mercenaria*;
[c] *Arctica islandica*;
[d] *Mya arenaria*.

wet weight in 1979. (Note that the 1970-71 samples were collected at the GSO.) Given the analytical uncertainties at these low concentrations, as well as the spacial and temporal differences in the samples, it is not possible at this time to say whether the apparent increase in PHCs is real or not. This also holds true for the Wickford samples. In the case of the Providence River samples, there appears to be an increase in PHC concentration in clams collected in 1973-1976 relative to those collected in 1970-71.

Values for PAHs in *Mercenaria mercenaria* from Dutch Island have been published by Pruell et al. (1984); they range from 1.5-1.8 ng/g wet weight and the major components are phenanthrene, fluoranthene and pyrene. Pruell and Norwood (1988) reported values of PAHs in hardshell clams collected in 1985-86 from several areas in Narragansett Bay ranging from the Providence River (average = 427 ng/g dry weight or about 43 ng/g wet weight, assuming 90% water content) to the mid-bay area (279 ng/g dry weight or about 28 ng/g wet weight). These values are considerably lower than those reported for *Mya arenaria* from Allen Harbor (230-346 ng/g wet weight; Quinn and Pruell, 1980b). Concentrations of PAHs in *Mytilus edulis* have been reported for two sites in Narragansett Bay as part of the National Status and Trends Mussel Watch Program (Boehm et al., 1987). The Conanicut Island station had a value of 295 ng/g dry weight (approximately 30 ng/g wet weight) and the Dyer Island station had a value of 405 ng/g dry weight (approximately 41 ng/g wet weight). Values for mussels collected in 1986 were 275 ng/g dry weight (about 28 ng/g wet weight) for Conanicut Island and 354 ng/g dry weight (about 35 ng/g wet weight) for Dyer Island (NOAA Tech Memo, 1987).

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VI. APPENDICES

Appendix 1

Narragansett Bay Project
Historical Dataset Summary Sheet

NBP Index Number:

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1) Title: Chemical monitoring of hydrocarbons in the Pawtuxet River.

2) Summary: See summary of published data.

3) Variables measured: Total hydrocarbons (ug/l), total polycyclic aromatic hydrocarbons (ug/l) and total suspended solids (mg/l) in industrial and municipal effluents, and in river water. Total hydrocarbons (ug/g dry) and total polycyclic aromatic hydrocarbons (ug/g dry) in sediments.

4) Sampling locations: Pawtuxet River (see maps for station locations).

5) Frequency of sampling: Water samples were collected from 6 point sources and 13 river stations under dry weather conditions. The samples were collected on 3 different dates. Sediment samples were collected from 1 station on 2 different dates.

6) Time span of data: June 1983 to September 1984.

7) Principal Investigators:
   Name: James G. Quinn and Eva J. Hoffman
   Organization: Graduate School of Oceanography
   Address: University of Rhode Island
   Narragansett, Rhode Island 02882
   Telephone: (401) 792-6219
   Funding: R. I. Department of Environmental Management with Clean Water Act 205j river basin planning funds (URI # 5-39409).

8) Citation for published data:
   James G. Quinn, Eva J. Hoffman, James S. Latimer and Constance G. Carey, 1985.
   A study of the water quality of the Pawtuxet River: Chemical monitoring and computer modeling of pollutants. Vol. I: Chemical monitoring of pollutants in the Pawtuxet River.
   Final Report submitted to the Division of Water Resources of the RI DEM, Graduate School of Oceanography, University of Rhode Island, 249 pp.

9) Location of original raw data: Room 130, Horn Laboratory, GSO/URI.

10) Person to contact for data: James G. Quinn.

11) Are original data computerized: No.

12) Not applicable.

13) Not applicable.

14) Not applicable.

15) Data quality: See methods section of published data.

16) Not applicable.

17) Not applicable.

18) Form filled out by: James G. Quinn.

19) Date: May 1988.

1-2 (cont'd)

Pawtuxet River

(water samples)

	41° N Latitude		71° W Longitude	
Station	min	sec	min	sec
1	47	20	36	00
2	42	15	37	25
2a	42	25	31	15
3	42	50	31	25
4	42	40	30	45
5	43	20	29	20
6	43	40	28	25
7	44	55	26	40
8	45	30	26	20
9	45	45	25	30
10	46	15	24	20
11	45	45	23	25
12	45	40	23	15
Rhodes sediment	46	10	23	40

A Study of the Water Quality of the Pawtuxet River:
Chemical Monitoring and Computer Modeling of Pollutants

Volume 1: Chemical Monitoring of Pollutants in the Pawtuxet River

A report submitted to the Division of Water
Resources of the Rhode Island Department of Environmental
Management.

by

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June, 1985

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TECHNICAL SUMMARY

Most of the water pollution problems resulting from sewage and industrial discharges into the Pawtuxet River have deep historical roots. The current attention of the press and public regarding these water quality issues has also occurred many times in the past. The most recent concerns by the public and governmental regulators centered around the tie-in of Ciba-Geigy wastewater to the Cranston treatment facility. Because of the long history of problems associated with industrial tie-ins, the public was concerned that this project might be as ineffective in pollution abatement as the previous experiences.

In this context, the Division of Water Resources of the Rhode Island Department of Environmental Management contracted the Graduate School of Oceanography and College of Engineering of the University of Rhode Island to design and complete a study of the water quality of the Pawtuxet River. The study began in June, 1983, and it addressed a number of issues regarding the effects of sewage and industrial discharges to the river. The objectives of this investigation were: (1) to monitor selected pollutants in the river; (2) to describe the hydraulic characteristics of the river; and (3) to use these data to develop, calibrate and verify a toxic pollutant water quality model for the river. The overall goal of the study was to provide a scientific basis for waste load allocations for the various dischargers along the Pawtuxet River.

The results of this study are reported in two volumes: the first is concerned with the chemical monitoring of the river and the second deals with the computer modeling aspects of the investigation. A summary of each phase of the study is included in the respective volumes.

Chemical Monitoring Summary

General

The specific objectives of this phase of the study were: (1) to measure the concentration patterns of selected organic and metal pollutants in the river as a function of location, proximity to large potential inputs, and flow conditions; (2) to determine the treatment efficiency for pollutants in the Cranston treatment facility before and after the Ciba-Geigy tie-in; and (3) to calculate the discharge rates of pollutants from the river into upper Narragansett Bay.

On three different dates chosen to represent various dry weather flow conditions in the river, water samples were collected at 13 stations including the Scituate and Flat River Reservoirs, north and south branches of the river, main stem of the river, and Pawtuxet Cove. Samples were also collected from two lower river stations during a rain storm. Effluent samples were obtained from the West Warwick, Warwick and Cranston treatment facilities as well as from American Hoechst Corporation, Original Bradford Soap Works, and the Ciba-Geigy Corporation. Influent samples were also collected from the Cranston facility in order to assess the treatment efficiency of this plant. Groundwater samples were collected from a rural site in North Scituate, a landfill in Cranston, and a location near Rhodes on the Pawtuxet. In addition, sediment core samples were collected from a depositional area in the river near Rhodes on the Pawtuxet.

The various samples were extracted with solvents to isolate the organic pollutants; the extracts separated into several fractions using silica gel column chromatography; and the fractions analyzed by gas chromatography using high resolution fused silica glass capillary columns. Selected fractions were also analyzed by combined gas chromatography-mass spectrometry to confirm the identification of specific organic pollutants. In the case of metal pollutants, the samples were acidified and analyzed by flame or flameless atomic absorption spectrophotometry, depending on the level of metal in the sample. The chemical detection limits for the various analyses are between 0.1 and 0.01 ug/l (parts per billion) using a flame ionization detector gas chromatograph, about 0.001 ug/l with an electron capture detector gas chromatograph, and between 1.0 ug/l (flame) and 0.01 ug/l (flameless) using atomic adsorption spectrophotometry. These detection limits, as obtained using state-of-the-art analytical techniques, are generally lower than those cited by the EPA (1982) and considerably lower than many commercial laboratories whose detection limits are about 10 ug/l. Therefore, although we report values for most samples, many contain only trace amounts of pollutants that would not be detected using methods currently employed by many government and industrial laboratories. Also, there are no water quality criteria for many of the pollutants that were measured in this study such as petroleum hydrocarbons, coprostanol (a fecal steroid in sewage), and substituted benzotriazoles (synthetic organics from the Ciba-Geigy plant).

Municipal Discharges

The three sewage treatment facilities occasionally experienced days when the treatment was poorer than usual. The Cranston plant generally exhibited lowest effluent concentrations for all compounds with the exception of nitrobenzene and the benzotriazoles which originate primarily from Ciba-Giegy. West Warwick usually had the highest average concentrations of suspended solids and petroleum hydrocarbons. Highest concentrations of coprostanol and phthalates were most often detected in the Warwick effluent. However, the variability of all compounds measured at the individual plants resulted in large standard deviations. Higher levels of hydrocarbons in the West Warwick plant were the only statistically significant difference between the three facilities.

A comparison of the metal data at the municipalities indicates that the concentrations were so variable that any potential differences between the plants were obscured. Maximum concentrations in the effluents were observed at the Warwick facility for all the metals (especially Cr), and minimum concentrations were observed at the Cranston plant for Cd, Cr, Cu and at the West Warwick plant for Pb, Ni, Ag and Zn. Treatment efficiencies for the Cranston treatment plant were generally good except for nickel, which for the most part, was not removed.

The chemical nature of the Cranston facility influent changed after the Ciba-Geigy tie-in; for example, increased levels of phthalates and nitrobenzene were detected as well as the addition of the substituted benzatriazoles. In general, this facility was very efficient in removing organic and metal pollutants, both before and after the tie-in.

Another way to compare the three facilities is on the basis of population. The pollutant discharges can be expressed in terms of average grams/capita/day; however, regarding the compounds analyzed, only coprostanol and possibly suspended solids are directly relevant to population. The data does not reveal any statistically significant differences between the three plants for these components suggesting that regardless of input, all three plants are about equal in their treatment of coprostanol and solids. For the metals, the data indicates that the three facilities have similar discharges (grams/capita/day) except for nickel, where the Warwick plant has a somewhat higher emission rate. All three plants on the Pawtuxet River had much lower per capita discharge rates for organic and most metal pollutants than the Fields Point treatment facility.

Industrial Discharges

Overall, the Bradford effluent had the lowest concentrations of all organic pollutants. American Hoechst showed some of the highest levels of suspended solids and petroleum hydrocarbons, and it was the sole source of 3,3'-dichlorobenzidine and a major source of 3,3'-dichlorobiphenyl. The highest levels of polycyclic aromatic hydrocarbons and phthalates were detected in the Ciba-Geigy effluent, and it was the only source of substituted benzotriazoles and nitrobenzene. Polychlorinated biphenyls were not detected in any of the industrial discharges.

Metal concentrations were quite variable in industrial effluents; for example, the highest and lowest cadmium concentrations were observed at American Hoechst and medium values were observed in the other point sources. Ciba-Geigy's effluent had the highest chromium and zinc concentrations but they were not very much greater than those at the other sources. The highest copper concentrations were observed in the effluent of American Hoechst, values were higher by at least an order of magnitude when compared to the other industries studied. American Hoechst's effluent also contained higher concentrations of nickel than the other industries.

River Stations

The concentrations of most pollutants in the river generally increased downstream from the headwaters, Scituate (station 1) and Flat River (station 2) reservoirs, to the Pawtuxet Cove (station 12). In general, river stations which were adjacent to point source discharges showed elevated concentrations of pollutants associated with that input; however, there were several exceptions to this trend. For example, on certain dates, relatively high values for lead were observed at stations 2A and 4 as well as elevated levels of PCBs at station 3; zinc had high concentrations at stations 7 and 8, and station 10 tended to have high values for many of the metals. None of these observations could be explained by the adjacent point sources which had generally lower concentrations for cadmium, lead and zinc than the river stations.

In the case of substituted benzotriazoles and zinc, there was a substantial reduction in the concentrations at river stations downstream of Ciba-Geigy. Also, based on our study of the efficiency at the Cranston facility, we have determined that the treatment of specific Ciba-Geigy chemicals was very effective. Therefore, we conclude that there was an overall decrease or elimination of several pollutants (e.g. phthalates, substituted benzotriazoles, nitrobenzene and zinc) which previously entered the river from Ciba-Geigy; and in this respect, the water quality of the river has improved as a result of the tie-in. However, due to the variability of the river values on the three sampling dates, we are not able to draw any firm conclusions as to improvements in the water quality of the river with respect to any of the other pollutants.

During wet weather conditions, the concentrations of urban runoff related components (e.g. petroleum hydrocarbons, high molecular weight polycyclic aromatic hydrocarbons and lead), all had a similar pattern showing peaks consistent with the first flush. The pattern of concentrations found at station 9 were repeated six to seven hours later at station 11 downstream, a time difference similar to the time of travel between the two stations. Urban runoff loading factors were used to estimate the urban runoff component discharges actually monitored, and the agreement of the predictions for most of the components was within a factor of two of the actual river discharge. In this section of the river, calculations suggest that the runoff from the interstate highway was largely responsible for the increases of pollutants. Based on the concentration of chloro-benzotriazole, there was no evidence for the resuspension of bottom sediments during this particular storm.

Sediment Cores

The historical record of pollutant input to the Pawtuxet River is recorded in the sediments. The distribution of organic contaminants with depth in sediment cores was consistent with known dates of inputs and events such as changes in formulation of industrial chemicals, the construction of wastewater treatment facilities and the construction and opening of interstate highway I-95. The concentration profiles of several metals indicated that some source inputs to the river may have decreased over the past 5 to 10 years due to better compliance with environmental regulations. The data also suggested that resuspension of river sediments occurs sometimes; while at other times, a net sedimentation was indicated.

Mass Discharges

The amount of coprostanol, phthalates, one of the substituted benzotriazoles, petroleum hydrocarbons and silver discharged to Pawtuxet Cove was consistent with the sum of the current known river point sources for these pollutants. The levels of most metals and suspended solids indicated that either additional sources were entering the river or resuspension of sediments contaminated by past discharges were reentering the system. All of these pollutants may then enter Narragansett Bay via the Providence River. For example, some of our recent studies have detected substituted benzotriazoles in sediments and hard shell clams, *Mercenaria mercenaria*, from the lower bay.

Table II-1.

Sampling dates

Dates	Municipal (24-hr composite)	Industrial (6 to 24-hr composite)	River-dry (all stations)	River-wet (Sta. 9 & 11)	Sediment (cores)	Ground-water
6/7/83	+	+ (A,B,C)	+			
6/21/83	+					
6/30/83					+	
8/2/83	+	+ (A,B)	+			
8/23/83	+					
9/13/83	+					
9/27/83	+					
10/18/83	+					
11/1/83	+					
11/3/83				+		
11/15/83	+					
11/29/83	+					
12/28/83	+					
1/24/84	+					
3/6/84	+	+ (A)				
3/27/84	+					
4/10/84					+	
4/24/84	+					
8/14/84	+	+ (A)				
8/29/84						+ (R)
9/10/84	+	+ (A)	+			
9/19/84						+ (S)

A = American Hoechst

B = Bradford Soap Works

C = Ciba-Geigy

R = Rhodes

S = Scituate.

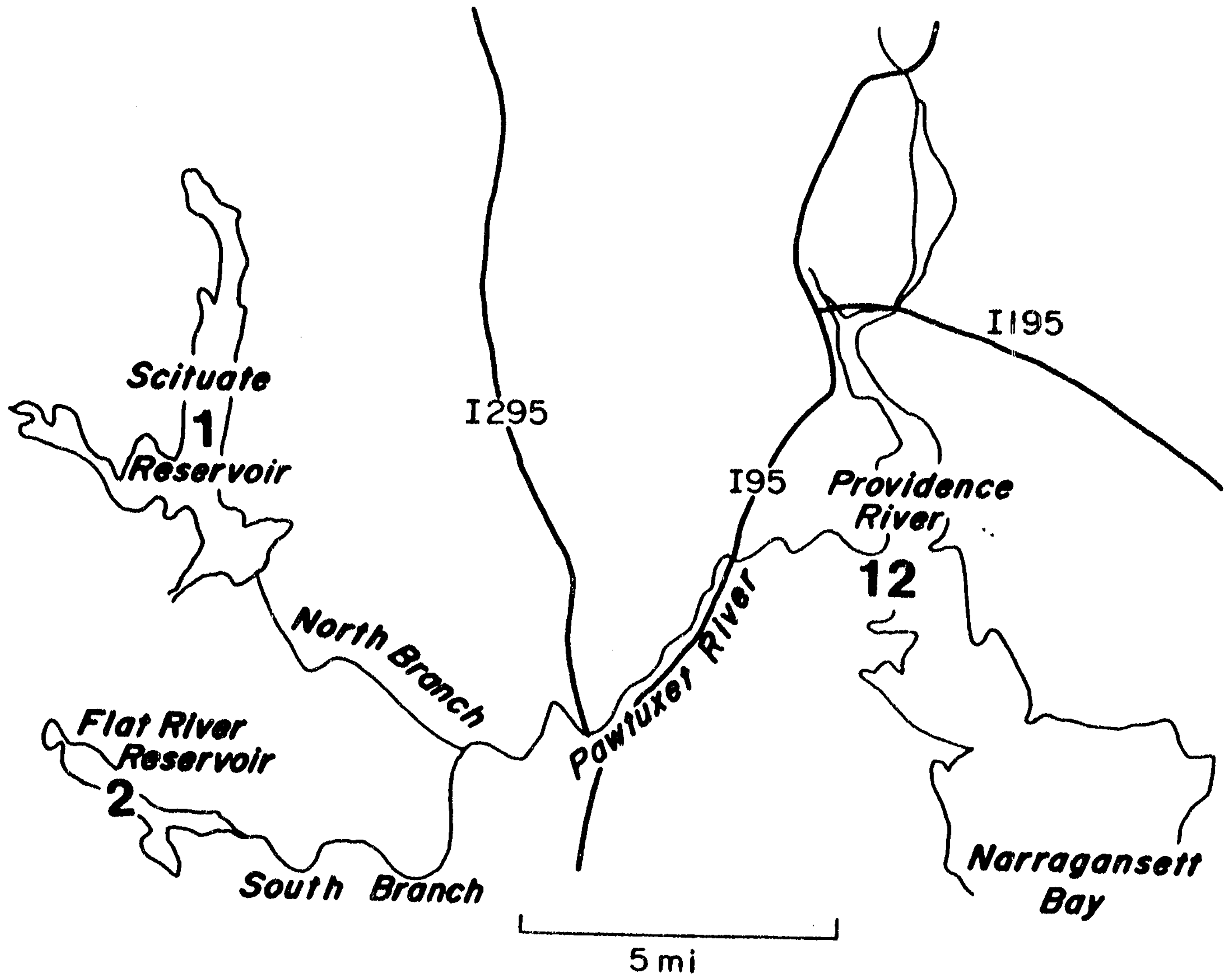

Figure II-1. Pawtuxet River upstream stations.

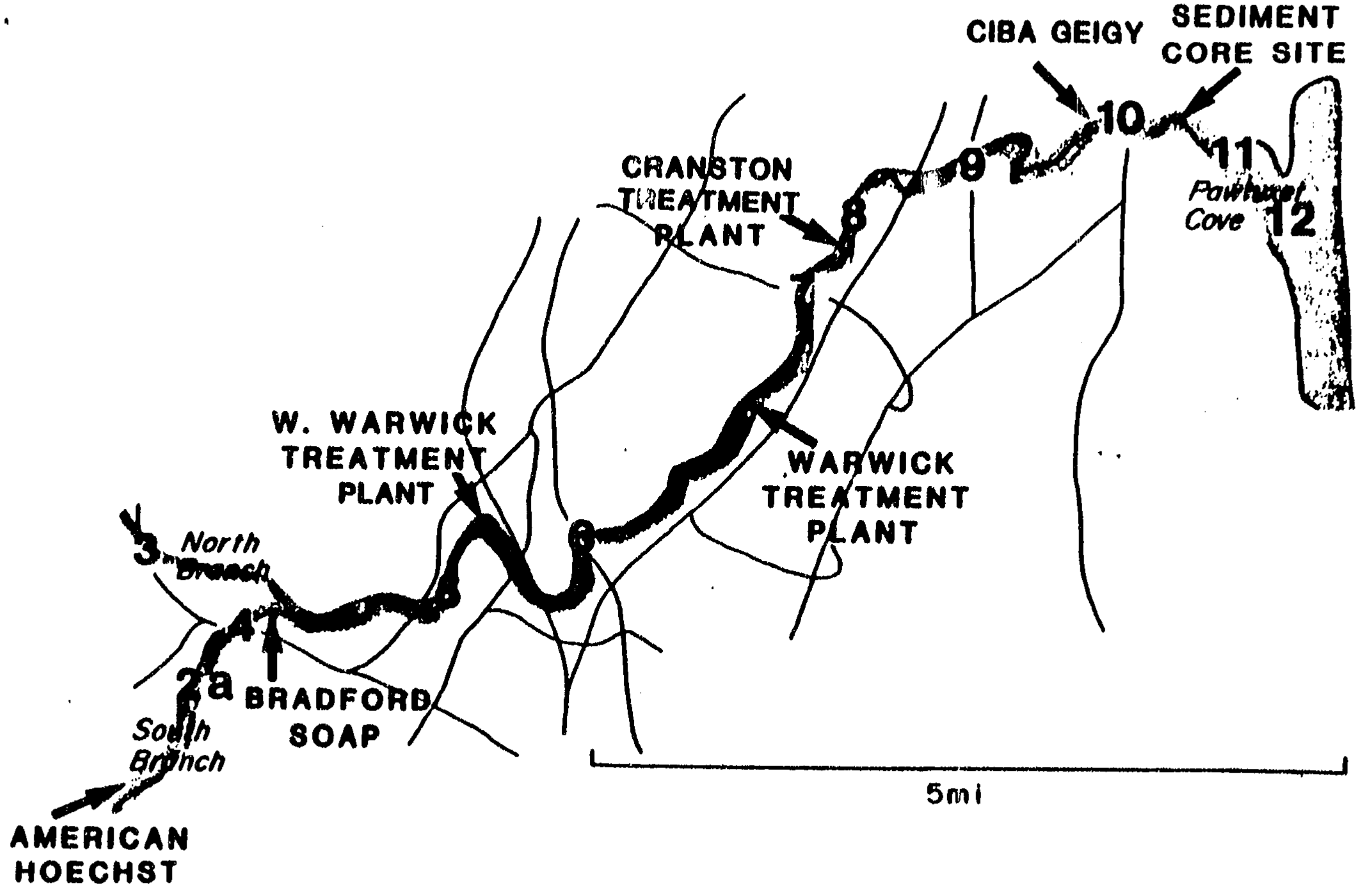

Figure II-2. Pawtuxet River downstream stations.

TABLE A-4
ORGANIC CHEMICAL ANALYSIS
WEST WARWICK TREATMENT FACILITY
(COMBINED PARTICULATE AND SOLUBLE FRACTIONS)

DATE	S.S. (MG/L)	HC (UG/L)	PAH (UG/L)	TOTAL PHTHALATE (UG/L)	COPROSTANOL (UG/L)	PCB (NG/L)
6/7/83	21	1110	ND	9	35	ND
6/21/83	148	15500	.33	371	131	ND
8/2/83	56	1470	.02	50	23	ND
8/23/83	55	2040	.23	1240	337	ND
9/13/83	38	3210	ND	1250	153	ND
9/27/83	66	3300	.68	374	787	ND
10/18/83	61	2910	.39	436	165	ND
11/1/83	32	1000	.32	387	78	ND
11/15/83	25	1240	.02	253	66	ND
11/29/83	46	3530	.02	903	106	ND
12/28/83	78	5240	.65	2110	305	ND
1/24/84	67	3220	.6	1140	158	ND
3/6/84	33	-	1.92	66	79	ND
3/27/84	16	-	.53	247	22	496
4/24/84	39	-	1.61	788	135	41
8/14/84	35	1080	.66	640	103	8.09
9/10/84	79.8	2330	1.58	1200	427	33.6
$\bar{X}$ ± S.D.	46.7±30	2440±1270	0.56±0.6	674±567	183±192	

- = NOT ANALYZED

ND = NONE DETECTED

TABLE A-5
ORGANIC CHEMICAL ANALYSIS
WARWICK TREATMENT FACILITY
(COMBINED PARTICULATE AND SOLUBLE FRACTIONS)

DATE	S.S. (MG/L)	HC (UG/L)	PAH (UG/L)	TOTAL PHTHALATE (UG/L)	COPROS-TANOL (UG/L)	PCB (NG/L)
6/7/83	20	687	ND	150	117	-
6/21/83	18	377	.35	178	59	-
8/2/83	24	303	.08	96	33	-
8/23/83	34	4890	.25	148	186	-
9/13/83	53	1170	.35	1880	280	-
9/27/83	37	434	.43	657	145	-
10/18/83	12	36	.47	98	25	-
11/1/83	28	383	.37	525	140	-
11/15/83	30	574	.37	1840	881	-
11/29/83	35	769	.66	2240	756	-
12/28/83	64	1510	1.01	1840	459	-
1/24/84	36	527	ND	818	320	-
3/6/84	42	-	1.4	726	476	-
3/27/84	23	-	.63	466	187	38.7
4/24/84	28	-	2.08	1140	282	120.0
8/14/84	8	130	.06	102	16	34.5
9/10/84	13	54	.3	523	30	25.7
X ± S.D.	29.7±14.5	540±430	.52±.54	790±730	260±260	55±44

- = NOT ANALYZED

ND = NONE DETECTED

TABLE A-6
ORGANIC CHEMICAL ANALYSIS
CRANSTON TREATMENT FACILITY INFLUENT
(COMBINED PARTICULATE AND SOLUBLE FRACTIONS)

DATE	SS (MG/L)	HC (UG/L)	PAH (UG/L)	TOTAL PHTHALATE (UG/L)	COPROS-TANOL (UG/L)	C18BENZO-TRIAZOLE (UG/L)	C1BENZO-TRIAZOLE (UG/L)	C10BENZO-TRIAZOLE (UG/L)	NITRO-BENZENE (UG/L)	PCB (NG/L)
6/7/83	174	7.52	53	58	665	ND	-	ND	ND	-
6/21/83	222	40.0	35	253	718	12	-	.12	1.87	-
8/2/83	225	11.2	.66	4750	1440	9.6	-	15.4	7819	-
8/23/83	285	5.40	1.29	965	2190	5.96	-	23	27800	-
9/13/83	222	4.43	5.92	2950	1820	40	-	61	178	-
9/27/83	161	3.88	ND	431	861	ND	-	24	83	-
10/18/83	162	5.64	3.67	5030	547	ND	-	72	441	-
11/1/83	181	3.40	4.2	5060	982	7.17	119	29	-	-
11/15/83	191	3.42	4.48	5090	1380	43	480	36	-	-
11/29/83	104	1.93	.36	1830	313	8.78	171	18	-	-
12/28/83	102	0.21	.49	1880	234	8.7	180	8.8	56	-
1/24/84	95	2.13	1.16	1820	270	19	220	77	48.5	-
3/6/84	180	-	6.39	3670	298	7.82	73	6.1	-	-
3/27/84	180	-	9.03	3300	483	ND	47	70	-	-
4/24/84	145	-	11.2	4070	379	5.7	156	55	-	29.4
8/14/84	255	2.89	4.88	9480	685	ND	ND	30	-	43
9/10/84	234	3.40	48.3	188	568	ND	1190	36	-	32
$\bar{X}$ ± S.D.	183±54	4.3±2.7	11.2±17	2990±2480	813±573	9.9±13	161±139	33±25	115±155	35±7.2

- = NOT ANALYZED

ND = NONE DETECTED

TABLE A-7
ORGANIC CHEMICAL ANALYSIS
CRANSTON TREATMENT FACILITY EFFLUENT
(COMBINED PARTICULATE AND SOLUBLE FRACTIONS)

DATE	S.S (MG/L)	HC (UG/L)	PAH (UG/L)	TOTAL PHTHALATE (UG/L)	COPROS-TANOL (UG/L)	C18BENZO-TRIAZOLE (UG/L)	C1BENZO-TRIAZOLE (UG/L)	C10BENZO-TRIAZOLE (UG/L)	NITRO-BENZENE (UG/L)	PCB (NG/L)
6/7/83	53	1240	.075	190	100	1.28	-	11.1	23	-
6/21/83	7	135	4.35	86	11	.19	-	.05	4.36	-
8/2/83	18	190	.31	97	10	ND	-	.53	12.2	-
8/23/83	25	237	.13	97	29	ND	-	.73	25	-
9/13/83	16	590	1.9	109	18	1.61	-	ND	88	-
9/27/83	18	239	.08	74	10	ND	-	1.76	10.5	-
10/18/83	13	310	.15	192	5	ND	-	1.7	15.2	-
11/1/83	17	274	.06	250	16	2.03	28	3.29	-	-
11/15/83	15	308	ND	181	18	ND	132	2.39	-	-
11/29/83	15	192	.08	99	18	.28	41	1.4	-	-
12/28/83	32	489	.17	316	44	ND	162	2.09	20	-
1/24/84	53	957	.8	546	98	1.45	121	8.9	9.2	-
3/6/84	12	-	1.72	87	13	2.32	10	ND	-	-
3/27/84	15	-	2.08	70	24	ND	20	1.96	-	16.1
4/24/84	30	-	.62	161	111	ND	30	4.23	-	5.69
8/14/84	22	357	.14	512	27	ND	ND	2.59	-	17.7
9/10/84	17	196	1.28	55	12	.24	68	.64	-	12.94
X ± S.D.	22±13	408±321	0.[illegible]±0.7	184±148	33±35	.55±.82	61±57	2.5±3.1	14.9±7	13.1±5.3

- = NOT ANALYZED

ND = NONE DETECTED

TABLE A-8
ORGANIC CHEMICAL ANALYSIS
JUNE 7, 1983 RIVER SURVEY
(COMBINED PARTICULATE AND SOLUBLE FRACTIONS)

STATION	S.S. (MG/L)	HC (UG/L)	PAH (UG/L)	C10BENZO-TRIAZOLE (UG/L)	NITRO-BENZENE (UG/L)	TOTAL PHTHALATE (UG/L)	3,3' DICHLORO-BENZIDINE (UG/L)	COPROS-TANOL (UG/L)	C18BENZO-TRIAZOLE (UG/L)
1	0.97	2	0.01	ND	ND	4	ND	0.10	ND
2	2.32	1	0.02	ND	ND	10	ND	0.20	ND
3	2.67	16	0.01	ND	ND	25	ND	0.30	ND
AM. HO.	276	21200	0.35	ND	ND	201	15	4.11	ND
4	4.49	55	ND	ND	ND	16	ND	0.20	ND
BRAD. 1	0.89	134	0.22	ND	ND	13	ND	0.02	ND
BRAD. 2	8.20	72	ND	ND	ND	14	ND	0.50	ND
5	5.01	41	0.02	ND	ND	20	ND	0.40	ND
WWTF	20.8	1110	ND	ND	ND	9	ND	35	ND
6	5.97	61	0.02	ND	ND	18	ND	1	ND
WTF	20	687	ND	ND	ND	150	ND	117	ND
7	8.69	57	0.01	ND	ND	8	ND	2	ND
CRAN.	174	1240	0.07	11.1	23	190	ND	100	1.30
8A	11.3	117	ND	ND	0.09	33	ND	4	ND
8B	36.1	631	0.05	4.3	0.07	65	ND	29	ND
8C	12.5	69	0.03	ND	ND	17	ND	3	ND
8D	9.97	90	0.04	ND	0.12	7	ND	3	ND
9	12.4	107	0.04	ND	0.21	34	ND	4	0.30
C.G.	58.7	1520	26	1200	153	1230	ND	NC	361
10	20.9	251	0.05	1.2	0.48	25	ND	7	0.80
11	23.1	144	0.03	2	0.1	15	ND	4	ND
12	9.76	77	0.01	1.7	0.07	7	ND	3	ND

NC = NOT CONFIRMED
ND = NONE DETECTED

TABLE A-9
ORGANIC CHEMICAL ANALYSIS
AUGUST 2, 1983 RIVER SURVEY
(COMBINED PARTICULATE AND SOLUBLE FRACTIONS)

STATION	S.S. (MG/L)	HC (UG/L)	PAH (UG/L)	C10BENZO-TRIAZOLE (UG/L)	NITRO-BENZENE (UG/L)	TOTAL PHTHALATE (UG/L)	3,3' DICHLORO-BENZIDINE (UG/L)	COPROS-TANOL (UG/L)	C18BENZO-TRIAZOLE (UG/L)
1	0.92	3.73	0.005	ND	ND	1.47	ND	0.07	ND
2	2.47	9.63	ND	ND	ND	1.65	ND	0.23	ND
3	1.18	11.8	0.025	ND	ND	1.87	ND	0.14	ND
AM. HO.	27.4	3340	0.121	ND	ND	71.6	20	ND	ND
4	5.71	101	1.470	ND	ND	7.54	ND	0.58	ND
BRAD 1	0.55	10	0.003	ND	ND	2.69	ND	ND	ND
BRAD 2	9.04	111	0.191	ND	ND	17.7	ND	0.27	ND
5	4.59	40.5	0.107	ND	ND	2.35	ND	0.33	ND
W.W.T.F.	56.2	1470	0.024	ND	ND	49.2	ND	23.2	ND
6	4.89	104	0.086	ND	ND	9.67	ND	3.12	ND
W.T.F.	24	303	0.095	0.11	ND	96.3	ND	33.6	ND
7	10.7	81	0.122	ND	ND	20.5	ND	2.62	ND
CRAN. EFF	18.4	190	0.308	0.53	12.20	97.2	ND	10.4	ND
CRAN.A	8.9	86	0.072	0.29	4.81	28.8	ND	6.66	ND
CRAN.B	8.09	85	0.019	0.23	7.46	16.1	ND	6.21	0.40
CRAN.C	20.8	169	0.059	0.70	5.29	29.3	ND	13.2	ND
CRAN.D	30.6	192	0.068	0.61	1.23	53.9	ND	28.9	ND
8A	11.8	77	0.164	0.01	0.99	6.93	ND	2.58	ND
8B	7.91	67	0.067	0.01	0.72	6.18	ND	2.57	ND
8C	16.9	148	0.066	0.02	0.27	3.62	ND	2.44	ND
8D	14.4	170	0.177	0.02	0.15	11.9	ND	3.74	ND
9	8.77	56	0.122	ND	0.07	31.3	ND	2.57	ND
10	8.99	74	0.131	0.03	0.18	19.1	ND	2.04	ND
11	6.95	69	0.091	0.21	ND	15.7	ND	1.57	ND
12	12.8	53	0.063	0.14	0.51	11.5	ND	1.73	ND

ND = NONE DETECTED

TABLE A-10
ORGANIC CHEMICAL ANALYSIS
SEPTEMBER 10, 1984 RIVER SURVEY
(COMBINED PARTICULATE AND SOLUBLE FRACTIONS)

STATION	S.S. (MG/L)	HC (UG/L)	PAH (UG/L)	C10BENZO-TRIAZOLE (UG/L)	TOTAL PHTHALATE (UG/L)	COPROS-TANOL (UG/L)	C18BENZO-TRIAZOLE (UG/L)	C1BENZO-TRIAZOLE (UG/L)	TOTAL PCBs (NG/L)	3,3' DICHLORO-BIPHENYL (NG/L)
1	0.95	6.22	0.15	ND	ND	0.06	ND	ND	1.08	ND
2	1.49	7.71	0.09	ND	2.89	0.01	ND	ND	1.85	ND
2A	8.90	168	1.59	ND	22.3	0.16	ND	ND	6.37	2.59
3	2.13	21.7	0.13	ND	13.1	0.11	ND	ND	38.9	ND
AM	40.1	3620	4.22	ND	143	2.12	ND	ND	ND	60.8
4	4.55	59.2	2.10	ND	52.5	0.13	ND	ND	6.99	3.47
5	3.11	34.1	0.99	ND	15	0.09	ND	ND	3.09	0.75
WW	79	2330	5.69	ND	1200	427	ND	ND	33.6	ND
6	7.66	85.8	1.33	ND	11.9	4.34	ND	ND	12.2	0.45
WA	12.7	54.3	0.26	ND	522	29.9	ND	ND	25.7	ND
7	7.39	77.4	0.17	ND	12.6	4.57	ND	ND	5.15	0.68
CR	16.6	196	1.28	0.64	55.4	12.1	0.24	68.4	12.9	ND
9	11	77.1	0.66	ND	44.9	6.09	0.14	29.9	5.15	0.61
10	11	76.3	0.44	ND	30.4	5.22	ND	20.4	7.26	1.15
11	15.8	105	0.55	ND	38.9	4.18	ND	6.14	10.5	0.59

ND = NONE DETECTED

TABLE A-11
ORGANIC CHEMICAL ANAYSIS
WET WEATHER SAMPLES
NOVEMBER 3,1983 STATIONS 9 AND 11
(COMBINED PARTICULATE AND SOLUBLE FRACTIONS)

STATION 9

SAMPLE	S.S. MG/L	TOTAL HC UG/L	PAH UG/L	C10BZT UG/L	CL BZT UG/L	PHTHALATE UG/L	3,3 DICL UG/L	COPROST UG/L	C18BZT UG/L	C1BZT UG/L
9	9.20	144	0.17	0.02	ND	33.6	ND	16.1	ND	3.25
10	9.40	110	0.33	0.01	ND	14.0	ND	11.3	ND	2.56
11	15.4	300	0.76	0.03	ND	20.2	ND	12.2	ND	2.37
12	19.9	534	3.15	0.05	ND	32.2	ND	13.6	ND	1.26
13	18.5	412	1.51	ND	ND	56.0	ND	15.9	ND	1.38
14	18.6	467	1.71	0.03	ND	38.2	ND	14.7	ND	3.14
15	22.6	489	1.31	0.03	ND	27.7	ND	16.7	ND	4.28
16	16.2	318	0.80	0.03	ND	30.7	ND	26.5	ND	4.93
17	15.1	378	0.41	ND	ND	17.9	ND	18.2	ND	3.37
18	13.2	274	0.41	ND	ND	18.3	ND	17.8	ND	2.32
19	13.2	215	0.48	ND	ND	22.4	ND	23.4	ND	2.70
20	11.9	176	0.26	ND	ND	21.4	ND	19.5	ND	2.46
21	10.8	179	0.23	ND	ND	27.8	ND	18.0	ND	2.82

STATION 11

SAMPLE	S.S. MG/L	TOTAL HC UG/L	PAH UG/L	C10BZT UG/L	CL BZT UG/L	PHTHALATE UG/L	3,3 DICL UG/L	COPROST UG/L	C18BZT UG/L	C1BZT UG/L
9	14.1	243	0.99	.04	ND	22.3	ND	.71	ND	.92
10	12.6	147	0.23	.01	ND	18.7	ND	16.2	ND	.89
11	12.1	181	0.09	ND	ND	16.8	ND	14.6	ND	.9
12	12.6	124	0.27	.04	ND	10.6	ND	14.1	ND	ND
13	10.8	125	0.16	.1	ND	24.8	ND	32.7	ND	1.74
14	13.2	206	0.42	.22	ND	11.9	ND	10.3	ND	1.21
15	14.4	171	0.26	.03	ND	17.2	ND	12.4	ND	1.31
16	18.1	328	2.15	.04	ND	14.5	ND	11.0	ND	.77
17	14.9	352	1.67	.02	ND	18.1	ND	12.6	ND	1.03
18	14.7	318	1.67	.06	ND	16.2	ND	9.85	ND	1.41
19	13.7	309	2.08	.03	ND	11.8	ND	7.86	ND	1.07
20	13.2	213	2.22	.14	ND	20.3	ND	9.45	ND	1.4
21	15.4	-	-	-	ND	10.1	ND	9.49	ND	1.11

- = NOT ANALYZED

ND = NONE DETECTED

TABLE A-12
ORGANIC CHEMICAL ANALYSIS
RHODES CORE JUNE 30, 1983
(UG/GM DRY WT)

SAMPLE (CM)	HC	PAH	C10-BZT	CL-BZT	PHTHALATE	COPROS-TANOL	C18-BZT	C1-BZT	C18-BHT ESTER
0-1	3650	29.1	15.6	6.90	121	96.5	15.5	222	ND
1-4	10900	156	20.4	6.60	106	97.6	ND	88.0	ND
4-7	9970	533	37.6	34.5	301	247	ND	156	ND
7-12	12100	183	39.7	118	103	140	18.3	2550	20.5
12-17	7940	17	0.35	117	79.9	121	ND	2500	ND
17-22	1120	12	0.13	106	24.5	67.6	ND	337	ND
22-27	6370	9.01	ND	80.2	42.4	89.9	ND	1560	ND
27-32	1360	28.1	ND	327	64.1	129	2.73	1900	4.53
32-37	5160	27.3	ND	981	53.9	102	ND	1400	ND
37-42	2810	25.2	ND	58.4	15.4	217	ND	789	ND
42-47	3080	30.5	ND	94.2	34.3	72.2	ND	1300	ND
47-52	3120	19.5	ND	26.3	11.9	114	ND	494	ND
52-58	3260	46.1	ND	1.60	23.1	199	ND	253	ND

ND = NONE DETECTED

TABLE A-13
ORGANIC CHEMICAL ANALYSIS
RHODES CORE APRIL 10, 1984
(UG/GM DRY WT)

SAMPLE (CM)	HC	PAH	C10-BZT	CL-BZT	PHTHALATE	COPROS-TANOL	C18-BZT	C1-BZT	C18-BHT ESTER	PCB
0-1	4670	49	14	97	173	84	ND	1310	ND	9.32
4-7	2920	78	15	69	92	60	8	371	3	2.44
12-17	2620	26	ND	314	50	92	30	985	4	8.33
22-27	4330	31	ND	1310	146	107	187	1730	12	14.4
32-37	3370	116	ND	5.9	73	133	ND	423	ND	1.84
42-47	5620	131	ND	1.2	69	415	ND	170	ND	4.12
52-57	4700	384	ND	.13	93	61	ND	2	5	.21
62-67	7000	146	ND	ND	132	61	ND	3	1	.21
72-77	10500	173	ND	ND	17	22	ND	9	12	ND
82-87	5640	62	ND	ND	9	7	ND	ND	ND	ND
92-97	3020	58	ND	ND	6	3	ND	ND	ND	---
102-107	8090	88	ND	ND	11	10	ND	ND	ND	---
117-122	1230	5.2	ND	ND	5	2	ND	ND	ND	---
132-137	24	.3	ND	ND	2	1	ND	ND	ND	---
147-150	56	.4	ND	ND	4	.2	ND	ND	ND	---

ND = NONE DETECTED

--- = NOT ANALYZED

Appendix 2

Narragansett Bay Project
Historical Dataset Summary Sheet

NBP Index Number:

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1) Title: Chemical monitoring of hydrocarbons in the Blackstone River.

2) Summary: See summary of published data.

3) Variables measured: Total hydrocarbons (ug/l), total and individual polycyclic aromatic hydrocarbons (ug/l) and total suspended solids (mg/l) in industrial and municipal effluents, and in river water.

4) Sampling locations: Blackstone River (see map for station locations).

5) Frequency of sampling: Water samples were collected from 4 point sources and 9 river stations under dry weather conditions. The samples were collected on 3 different dates.

6) Time span of data: July 1985 to October 1985.

7) Principal Investigators:
   Name: James G. Quinn
   Organization: Graduate School of Oceanography
   Address: University of Rhode Island
   Narragansett, Rhode Island 02882
   Telephone: (401) 792-6219
   Funding: Narragansett Bay Project (URI # 5-39487).

8) Citation for published data:
   James G. Quinn, James S. Latimer, Constance G. Carey, John T. Ellis, and Jinshu Zheng, 1987.
   Development of a one dimensional water quality model for the Blackstone River.
   Part 1: Chemical monitoring of pollutants in the Blackstone River.
   Final report submitted to the Narragansett Bay Project Office. Graduate School of Oceanography, University of Rhode Island, 171 pp.

9) Location of original raw data: Room 130, Horn Laboratory, GSO/URI.

10) Person to contact for data: James G. Quinn.

11) Are original data computerized: Yes.

12) a. MacIntosh Computer using 1 MS Excell Word;
    b. Room 130, Horn Laboratory, GSO/URI;
    c. James G. Quinn.

13) Are summarized data computerized: yes.

14) a. Summary statistics;
    b. MacIntosh Computer using MS Excell;
    c. Room 130, Horn Laboratory, GSO/URI;
    d. James G. Quinn.

15) Data quality: See methods section of published data.

16) Not applicable.

17) Not applicable.

18) Form filled out by: James G. Quinn

19) Date: May 1988.

2-2 (cont'd)

Blackstone River

(water samples)

Station	41° N Latitude			71° W Longitude	
	deg	min	sec	min	sec
1	42	00	00[a]	33	10
2	42	01	00[a]	32	45
3	42	00	20[a]	30	45
4		58	15	28	15
5		57	10	27	10
6		55	40	25	50
7		54	40	24	10
8		53	50	23	25
9		52	40	23	05

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[a] note 42° latitude.

Final Report
to the
Narragansett Bay Project Office

Development of a One Dimensional Water Quality Model for the Blackstone River;

Part 1: Chemical Monitoring of Pollutants in the Blackstone River

by

James G. Quinn, James S. Latimer, Constance G. Carey,
John T. Ellis, and Jinshu Zheng

Graduate School of Oceanography
University of Rhode Island
Narragansett, Rhode Island 02882

August 1987

SUMMARY

Water samples were collected from nine stations on the Blackstone River and effluent samples were collected from four major point sources on the river. The samples were collected on three dates during the summer/fall of 1985 and analyzed for a variety of organic and metal pollutants.

In most cases, the organic pollutants were strongly associated with the particulate phase of the samples. The average concentrations of hydrocarbons, phthalates, coprostanol, and hexachlorocyclohexanes (HCHs) were highest in the Woonsocket Wastewater Treatment Plant effluent. Corning/G.T.E. Products usually had the highest levels of suspended solids, total polycyclic aromatic hydrocarbons (PAHs), and total polychlorinated biphenyls (PCBs) in its effluent. The Okonite Company effluent generally had low concentrations of all components measured. The S.A.B. Nife Inc. effluent, on the one date it was sampled, showed low concentrations for most species; however, it did contain high amounts of HCHs and PAHs.

All of the monitored point source effluents showed relatively similar concentrations of cadmium and lead; the former was usually in the dissolved fraction and the latter tended to be in the particulate phase of the samples. The G.T.E. effluent had the highest levels of chromium and silver (both were mostly dissolved) and it was similar to the Woonsocket Plant, in that it had relatively high levels of dissolved copper and nickel. Based on the one date it was sampled, Nife had low levels of all six metals analyzed in this study.

Generally, the point source effluents were higher than the river in their concentrations of suspended solids, coprostanol, and

phthalates; however, the levels of hydrocarbons, PAHs, and PCBs in the river were frequently comparable or higher than the values detected in the point sources. River stations directly downstream of point sources usually did not show elevated concentrations of organic compounds associated with the input; in the case of the HCHs, however, the Woonsocket Plant apparently influenced the next two downstream stations.

The concentrations of organic components in the river did not show any prominent trends with distance. However, the first station (on the Branch River) usually had the lowest concentration of all components, and the second station (Massachusetts-Rhode Island line) generally had the highest levels of these components.

The last survey (October) had the highest average river concentration of suspended solids, hydrocarbons, PAHs, PCBs, and coprostanol. Since the effluent concentrations from the point sources were higher during this survey, this may account for the higher river pollutant values on this date. In addition, the flow rate of the river was twice as high as the other two surveys, perhaps causing resuspension of sediment containing these organic contaminants.

The average river concentrations of the metals varied somewhat for the three dates. In the case of particulate copper and lead, the variability correlated with the flow rates of the river such that higher rates may have caused resuspension and remobilization of metals associated with the bottom sediments. For many of the other metals, the changes over the three dates were not large. Cadmium, copper, and nickel were mostly in the dissolved phase in the river samples; while chromium, lead and silver were associated with the suspended load of the river. For most of the metals, the point source discharges into the river had no observable affect on either the concentration or the fractionation of the metals in the receiving water.

In general, the concentration of metals either remained constant or decreased slightly from station 2 through station 9. Station 1 showed substantially reduced metal concentrations to the point where most samples had levels at or near the detection limits of the methods employed. For the remainder of the river, most stations had metal concentrations greater than the fresh water chronic criteria; however, the concentrations of chromium (presumably Cr (III)) and nickel were found to be less than this criteria. In addition, generally all of the stations had levels significantly less than the acute criteria designation except in the case of copper, where the concentrations exceeded the criteria by 50% on average. Finally, for chromium, copper, and silver, the point sources tended to have higher concentrations than the river; for cadmium, the river had higher concentrations; and for nickel and lead, the concentrations were variable.

The largest amount of most of the organics discharged from point sources to the Blackstone River was from the Woonsocket Wastewater Treatment Plant. Compared to the municipalities previously studied on the Pawtuxet River, the Woonsocket Plant had smaller or comparable mass loadings of hydrocarbons, PAHs, coprostanol, and phthalates, but larger loads of suspended solids. Overall, Woonsocket, like the municipalities on the Pawtuxet, had much lower loads of suspended solids and all organic compounds than the Fields Point plant in Providence.

In order to determine the mass balance of organics in the Blackstone River, it was necessary to include station 2 as part of the point source summation because of the high values (apparently derived from upstream in Massachusetts) detected at this location. The calculation of the mass balance showed that suspended solids, PAHs and PCBs were in balance with what could be accounted for by the combined sources. Most of the other organic contaminants showed that less was transported out of the river than could be accounted for by the point sources suggesting deposition to the river sediments. In the case of g-HCH, the values indicated that about 20% more was transported out of the river than could be accounted for by the mass balance; resuspension of river sediments containing this compound may be responsible for the observed values.

The Woonsocket Municipal Treatment Plant was the major point source of metals to the river, contributing significant amounts of all the metals when compared to the industrial discharges. However, except for silver, this source was relatively insignificant compared to the metal loadings coming from the Massachusetts portion of the river. Within the variability of the data, it appears that most of the lead that entered the river was transported the length of the river and then discharged into the Seekonk River. As for the other metals, about 50% were transported into the Seekonk River and the remaining 50% were probably sedimented out in the Blackstone River. In addition, the Seekonk River, because it is an estuary itself, may be a major sink for the metals (and organics) that are discharged into it and further investigation of this "river" would need to be undertaken in order to determine the extent of the pollutants that actually enter the Providence River and Upper Narragansett Bay from the Seekonk.

Compared to previous mass discharge estimates of other municipal facilities, the Woonsocket Treatment Plant had generally greater metal discharges than those on the Pawtuxet, yet substantially less than the Fields Point discharge. On the basis of the mass of metals discharged, the Blackstone River tended to be less than the Pawtuxet River, except in the case of chromium where it had higher mass loadings than the Pawtuxet.

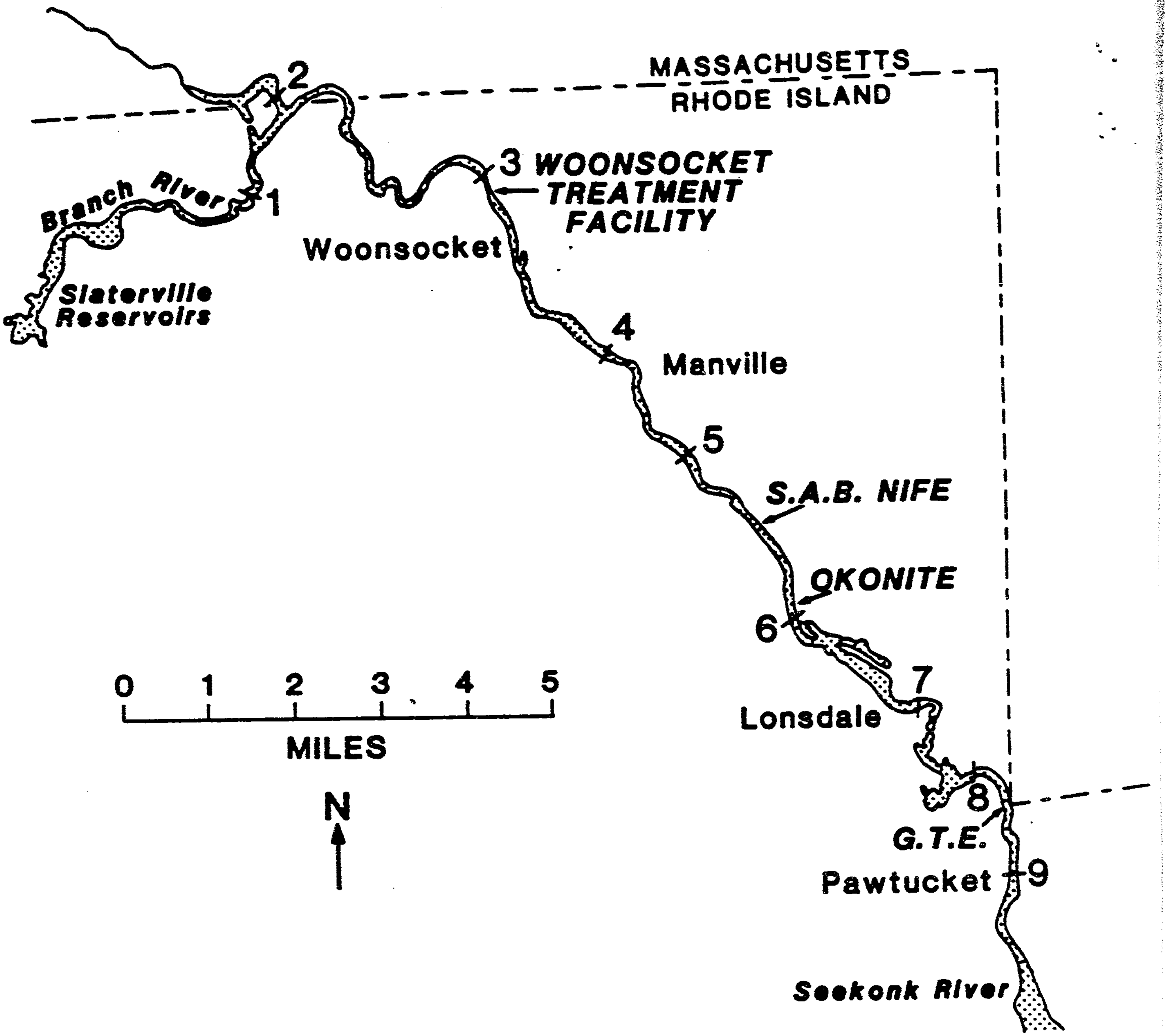

Figure II-1. Sampling locations on the Blackstone River.

A-1

BLACKSTONE RIVER
JULY 8, 1985
TOTALS

STATION	S.S. MG/L	HC UG/L	PAH UG/L	PHTHAL UG/L	COPROST UG/L	PCB NG/L
1	1.96	15.7	0.14	2.65	0.14	4.28
2	6.68	308	0.42	13.6	0.21	24.3
3	4.80	30.3	0.18	4.16	0.09	8.25
WOON	18.6	504	0.20	250	14.5	ND
4A	6.32	43.8	0.24	10.7	0.21	13.3
4B	12.2	170	0.37	10.1	0.50	17.2
4C	9.90	55.00	0.32	14.2	0.47	17.8
4D	6.79	49.5	0.20	16.0	0.33	13.3
5	8.09	55.3	0.22	17.4	0.31	13.1
NIFE	NC	NC	NC	NC	NC	NC
OKONITE	0.40	14.2	0.33	106	ND	ND
6	5.84	28.5	0.75	3.45	0.14	4.45
7	5.09	26.5	0.40	2.60	0.06	6.27
8	6.62	38.5	0.35	5.00	ND	ND
GTE	13.2	19.2	0.58	2.12	ND	ND
9	8.38	87.2	0.26	4.45	ND	18.8

ND = NONE DETECTED

NC = NOT COLLECTED

SOLUBLE FRACTION BLACKSTONE RIVER JULY 8, 1985

STA.	S.S. MG/L	H.C. UG/L	PAH UG/L	COP UG/L	CHO UG/L	BBP UG/L	DHP UG/L	DOP UG/L	PHT UG/L	C1BZT UG/L	PCB NG/L
1	0.0	4.67	0.05	0.00	0.77	0.19	1.42	0.00	1.62	0.00	0.00
2	0.0	12.5	0.11	0.00	2.80	0.52	8.58	0.00	9.10	0.00	3.72
3	0.0	8.98	0.13	0.00	0.00	0.28	2.50	0.34	3.12	0.00	4.02
4a	0.0	7.94	0.09	0.00	0.94	0.19	8.24	0.11	8.54	0.00	1.26
4b	0.0	17.9	0.11	0.00	0.00	0.20	6.76	0.30	7.25	0.00	0.00
4c	0.0	8.93	0.12	0.00	0.00	0.29	12.6	0.00	12.9	0.00	0.00
4d	0.0	9.54	0.12	0.00	0.00	0.44	14.1	0.19	14.7	0.00	0.00
5	0.0	19.9	0.12	0.00	3.58	0.51	15.4	0.23	16.2	0.00	0.94
6	0.0	7.73	0.16	0.00	0.43	0.22	1.69	0.24	2.15	0.00	0.68
7	0.0	6.62	0.14	0.00	0.43	0.17	1.18	0.10	1.45	0.00	1.42
8	0.0	15.9	0.09	0.00	1.42	0.34	3.73	0.00	4.07	0.00	0.00
9	0.0	11.7	0.10	0.00	0.64	0.27	2.71	0.13	3.10	0.00	3.82
AVE.	0.0	11.0	0.11	0.00	0.92	0.30	6.58	0.14	7.02	0.00	1.32
WTP	0.0	47.4	0.11	0.00	0.00	3.05	15.4	0.0	18.5	0.00	0.00
OKO	0.0	12.5	0.25	0.00	0.43	1.85	58.4	0.27	60.6	0.00	0.00
NFE											
GTE	0	15.7	0.51	0.00	0.10	0.15	1.83	0.09	2.07	0.00	0.00

A-3

SOLUBLE FRACTION BLACKSTONE RIVER JULY 8, 1985

PAHS

STA.	NAP UG/L	ANT UG/L	ANE UG/L	FLO UG/L	PHN UG/L	ANC UG/L	FLU UG/L	PYR UG/L	BaA UG/L	CHR UG/L	BbF UG/L	BkF UG/L	BaP UG/L	INP UG/L	DaA UG/L	BgP UG/L	TOT UG/L
1	0.00	0.0	0.00	0.00	0.00	0.0	0.02	0.01	0.00	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.05
2	0.00	0.0	0.00	0.00	0.02	0.0	0.03	0.03	0.01	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.11
3	0.02	0.0	0.01	0.01	0.02	0.0	0.02	0.02	0.00	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.13
4a	0.01	0.0	0.01	0.01	0.01	0.0	0.02	0.02	0.00	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.09
4b	0.01	0.0	0.01	0.01	0.01	0.0	0.02	0.03	0.01	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.11
4c	0.01	0.0	0.01	0.01	0.01	0.0	0.03	0.03	0.00	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.12
4d	0.00	0.0	0.00	0.01	0.01	0.0	0.04	0.03	0.00	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.12
5	0.01	0.0	0.01	0.01	0.01	0.0	0.03	0.03	0.00	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.12
6	0.00	0.0	0.01	0.01	0.02	0.0	0.05	0.04	0.00	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.16
7	0.01	0.0	0.01	0.01	0.02	0.0	0.05	0.03	0.00	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.14
8	0.00	0.0	0.00	0.00	0.01	0.0	0.04	0.02	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.09
9	0.00	0.0	0.00	0.00	0.02	0.0	0.04	0.03	0.00	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.10
WTP	0.03	0.0	0.00	0.04	0.01	0.0	0.00	0.00	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.11
OKO	0.00	0.0	0.01	0.03	0.02	0.0	0.03	0.02	0.01	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.25
NFE																	
GTE	0.05	0.0	0.03	0.04	0.20	0.0	0.09	0.06	0.00	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.51

A-4

PARTICULATE FRACTION BLACKSTONE RIVER JULY 8, 1985

STA.	S.S. MG/L	H.C. UG/L	PAH UG/L	COP UG/L	CHO UG/L	BBP UG/L	DHP UG/L	DOP UG/L	PHT UG/L	C1BZT UG/L	PCB NG/L
1	1.96	11.0	0.09	0.14	1.03	0.18	0.72	0.13	1.03	0.00	4.28
2	6.68	296	0.31	0.21	1.27	0.12	3.78	0.55	4.45	0.00	20.6
3	4.80	21.3	0.05	0.09	0.97	0.14	0.85	0.04	1.04	0.00	4.23
4a	6.32	35.9	0.15	0.21	1.50	0.40	1.68	0.08	2.16	0.00	12.0
4b	12.2	152	0.26	0.50	3.87	0.35	2.30	0.23	2.89	0.00	17.2
4c	9.90	46.1	0.20	0.47	1.95	0.26	0.98	0.02	1.26	0.00	17.8
4d	6.79	40.0	0.08	0.33	1.72	0.28	0.98	0.00	1.26	0.00	13.3
5	8.09	35.4	0.10	0.31	2.54	0.22	1.00	0.07	1.28	0.00	12.2
6	5.84	20.8	0.59	0.14	1.79	0.19	1.05	0.06	1.30	0.00	3.77
7	5.09	19.9	0.26	0.06	0.68	0.21	0.94	0.00	1.15	0.00	5.48
8	6.62	22.5	0.26	0.00	2.09	0.00	0.93	0.00	0.93	0.00	0.00
9	8.38	75.5	0.16	0.00	1.32	0.00	1.35	0.00	1.35	0.00	15.0
AVE.	6.89	64.7	0.21	0.20	1.73	0.20	1.38	0.10	1.67	0.00	10.49
WTP	18.6	456	0.09	14.5	23.9	1.39	230	0.00	232	0.00	0.00
OKO	0.40	1.64	0.08	0.00	0.00	0.00	45.0	0.00	45.0	0.00	0.00
NFE											
GTE	13.2	3.58	0.07	0.00	0.00	0.05	0.00	0.00	0.05	0.00	0.00

PARTICULATE FRACTION BLACKSTONE RIVER JULY 8, 1985

PAHS

STA.	NAP UG/L	ANT UG/L	ANE UG/L	FLO UG/L	PHN UG/L	ANC UG/L	FLU UG/L	PYR UG/L	BaA UG/L	CHR UG/L	BbF UG/L	BkF UG/L	BaP UG/L	INP UG/L	DaA UG/L	BgP UG/L	TOT UG/L
1	0.0	0.0	0.00	0.00	0.02	0.0	0.05	0.02	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.09
2	0.0	0.0	0.00	0.00	0.00	0.0	0.06	0.07	0.00	0.06	0.0	0.0	0.00	0.0	0.1	0.0	0.31
3	0.0	0.0	0.00	0.00	0.00	0.0	0.02	0.01	0.00	0.01	0.0	0.0	0.00	0.0	0.0	0.0	0.05
4a	0.0	0.0	0.00	0.00	0.01	0.0	0.04	0.02	0.00	0.01	0.0	0.0	0.01	0.0	0.0	0.0	0.15
4b	0.0	0.0	0.00	0.00	0.03	0.0	0.06	0.03	0.01	0.02	0.0	0.0	0.00	0.0	0.0	0.0	0.26
4c	0.0	0.0	0.00	0.00	0.02	0.0	0.06	0.02	0.01	0.01	0.0	0.0	0.01	0.0	0.0	0.0	0.20
4d	0.0	0.0	0.00	0.00	0.01	0.0	0.02	0.01	0.00	0.01	0.0	0.0	0.01	0.0	0.0	0.0	0.08
5	0.0	0.0	0.00	0.00	0.01	0.0	0.03	0.02	0.00	0.01	0.0	0.0	0.01	0.0	0.0	0.0	0.10
6	0.0	0.0	0.00	0.00	0.13	0.0	0.20	0.12	0.00	0.05	0.0	0.0	0.02	0.0	0.0	0.0	0.59
7	0.0	0.0	0.00	0.00	0.04	0.0	0.09	0.04	0.00	0.02	0.0	0.0	0.01	0.0	0.0	0.0	0.26
8	0.0	0.0	0.01	0.00	0.05	0.0	0.07	0.04	0.00	0.02	0.0	0.0	0.01	0.0	0.0	0.0	0.26
9	0.0	0.0	0.00	0.00	0.03	0.0	0.06	0.03	0.01	0.02	0.0	0.0	0.01	0.0	0.0	0.0	0.16
WTP	0.0	0.0	0.00	0.00	0.02	0.0	0.04	0.00	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.09
OKO	0.0	0.0	0.00	0.00	0.00	0.0	0.00	0.00	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.08
NFE																	
GTE	0.0	0.0	0.00	0.00	0.00	0.0	0.07	0.00	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.07

A-6

BLACKSTONE RIVER
AUGUST 20, 1985
TOTALS

STATION	S.S. MG/L	HC UG/L	PAH UG/L	PHTHAL UG/L	COPROST UG/L	PCB NG/L
1	3.34	11.5	0.11	2.39	0.14	5.10
2	4.67	72.2	0.33	3.88	0.28	31.6
3	7.01	43.5	0.21	7.11	0.14	29.1
WOON	44.2	932	1.07	169	7.46	ND
4A	8.36	66.0	0.45	1.71	0.20	31.9
4B	5.69	58.3	0.20	1.60	0.22	18.3
4C	4.19	31.9	0.24	1.59	0.25	20.2
4D	7.24	60.2	0.30	1.93	0.29	20.5
5	6.50	54.6	0.26	1.18	0.16	21.7
NIFE	NC	NC	NC	NC	NC	NC
OKONITE	0.54	16.2	0.40	64.1	ND	3.28
6	5.74	29.2	0.67	15.3	0.09	15.0
7	4.91	24.8	0.69	4.79	0.07	19.1
8	4.45	25.1	0.22	1.45	0.07	13.5
GTE	293	109	1.12	97.6	1.16	37.0
9	6.46	59.1	0.34	1.79	0.15	22.4

ND = NONE DETECTED
NC = NOT COLLECTED

A-7

SOLUBLE FRACTION BLACKSTONE RIVER AUGUST 20,1985

STA.	S.S. MG/L	H.C. UG/L	PAH UG/L	COP UG/L	CHO UG/L	BBP UG/L	DHP UG/L	DOP UG/L	PHT UG/L	C1BZT UG/L	PCB NG/L
1	0.0	3.80	0.03	0.00	0.88	0.63	0.72	0.03	1.38	0.00	0.00
2	0.0	7.12	0.08	0.06	0.44	0.00	0.59	0.04	0.63	0.00	4.35
3	0.0	5.71	0.11	0.00	0.53	0.46	5.65	0.07	6.18	0.00	2.80
4a	0.0	6.33	0.14	0.00	0.22	0.31	0.63	0.00	0.94	0.00	6.78
4b	0.0	11.2	0.11	0.00	0.20	0.18	0.00	0.99	0.83	0.00	4.34
4c	0.0	1.77	0.13	0.07	1.14	0.12	0.95	0.05	1.11	0.00	3.41
4d	0.0	1.77	0.13	0.07	1.14	0.12	0.95	0.05	1.11	0.00	3.41
5	0.0	7.53	0.13	0.00	0.15	0.12	0.44	0.00	0.56	0.00	3.33
6	0.0	4.54	0.14	0.00	0.38	0.09	14.8	0.00	14.9	0.00	1.97
7	0.0	5.19	0.23	0.00	0.22	0.13	4.00	0.16	4.28	0.00	8.86
8	0.0	5.80	0.08	0.00	0.00	0.11	0.54	0.00	0.65	0.00	0.00
9	0.0	8.90	0.09	0.00	0.13	0.07	0.65	0.00	0.72	0.00	2.89
AVE.	0.0	5.81	0.12	0.02	0.45	0.19	2.49	0.12	2.77	0.00	3.51
WTP	0.0	38.5	0.10	0.48	2.14	1.61	11.5	0.00	13.1	0.00	0.00
OKO	0.0	5.22	0.10	0.00	0.00	1.59	35.9	0.20	37.7	0.00	0.00
NFE											
GTE	0.0	2.40	0.81	0.00	0.00	0.00	2.61	0.00	2.61	0.00	0.00

SOLUBLE FRACTION BLACKSTONE RIVER AUGUST 20,1985

PAHS

STA.	NAP UG/L	ANT UG/L	ANE UG/L	FLO UG/L	PHN UG/L	ANC UG/L	FLU UG/L	PYR UG/L	BaA UG/L	CHR UG/L	BbF UG/L	BkF UG/L	BaP UG/L	INP UG/L	DaA UG/L	BgP UG/L	TOT UG/L
1	0.00	0.0	0.00	0.00	0.00	0.0	0.01	0.01	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.03
2	0.00	0.0	0.00	0.00	0.01	0.0	0.02	0.03	0.00	0.01	0.0	0.0	0.00	0.0	0.0	0.0	0.08
3	0.04	0.0	0.01	0.00	0.00	0.0	0.03	0.03	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.11
4a	0.02	0.0	0.01	0.01	0.01	0.0	0.04	0.04	0.00	0.01	0.0	0.0	0.00	0.0	0.0	0.0	0.14
4b	0.02	0.0	0.01	0.00	0.02	0.0	0.02	0.03	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.11
4c	0.03	0.0	0.01	0.01	0.01	0.0	0.02	0.03	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.13
4d	0.03	0.0	0.01	0.01	0.01	0.0	0.02	0.03	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.13
5	0.01	0.0	0.01	0.01	0.01	0.0	0.03	0.03	0.00	0.01	0.0	0.0	0.00	0.0	0.0	0.0	0.13
6	0.01	0.0	0.01	0.00	0.03	0.0	0.05	0.04	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.14
7	0.01	0.0	0.01	0.01	0.05	0.0	0.08	0.05	0.00	0.01	0.0	0.0	0.00	0.0	0.0	0.0	0.23
8	0.00	0.0	0.00	0.00	0.01	0.0	0.02	0.02	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.08
9	0.00	0.0	0.00	0.00	0.01	0.0	0.03	0.03	0.00	0.01	0.0	0.0	0.00	0.0	0.0	0.0	0.09
WTP	0.00	0.0	0.00	0.00	0.00	0.0	0.02	0.00	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.10
OKO	0.02	0.0	0.00	0.01	0.01	0.0	0.02	0.01	0.00	0.01	0.0	0.0	0.00	0.0	0.0	0.0	0.10
NFE																	
GTE	0.15	0.0	0.05	0.00	0.42	0.0	0.12	0.07	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.81

A-9

PARTICULATE FRACTION BLACKSTONE RIVER AUGUST 20, 1985

STA.	S.S. MG/L	H.C. UG/L	PAH UG/L	COP UG/L	CHO UG/L	BBP UG/L	DHP UG/L	DOP UG/L	PHT UG/L	C1BZT UG/L	PCB NG/L
1	2.48	7.69	0.08	0.14	0.58	0.10	0.88	0.03	1.01	0.00	5.10
2	4.67	65.1	0.25	0.22	0.57	0.37	2.81	0.08	3.25	0.00	27.2
3	7.02	37.7	0.10	0.14	0.38	0.18	0.75	0.00	0.93	0.00	26.3
4a	8.36	59.7	0.31	0.20	0.80	0.07	0.70	0.0	0.75	0.00	25.1
4b	5.69	47.1	0.09	0.22	0.90	0.12	0.61	0.03	0.77	0.00	14.0
4c	4.19	30.2	0.11	0.18	0.70	0.05	0.43	0.00	0.48	0.00	16.8
4d	7.24	58.5	0.17	0.22	0.74	0.11	0.69	0.02	0.82	0.00	17.1
5	6.50	47.1	0.13	0.16	0.00	0.06	0.54	0.0	0.62	0.00	18.4
6	5.74	24.6	0.53	0.09	0.66	0.06	0.38	0.03	0.47	0.00	13.0
7	4.91	19.6	0.46	0.07	0.60	0.08	0.40	0.03	0.51	0.00	10.2
8	4.45	19.3	0.14	0.07	0.42	0.10	0.66	0.05	0.80	0.00	13.5
9	6.48	50.2	0.25	0.15	0.32	0.19	0.84	0.04	1.07	0.00	19.5
AVE.	5.64	38.9	0.22	0.15	0.56	0.12	0.81	0.02	0.96	0.00	17.2
WTP	44.3	894	0.97	6.98	22.5	0.89	154	1.0	156.3	0.00	0.00
DKO	0.54	11.0	0.30	0.00	0.00	0.00	26.4	0.00	26.4	0.00	0.00
NFE											
GTE	293	107	0.31	1.16	5.33	0.00	95.01	0.00	95.01	0.00	37.0

PARTICULATE FRACTION BLACKSTONE RIVER AUGUST 20, 1985

PAHS

STA.	NAP UG/L	ANT UG/L	ANE UG/L	FLO UG/L	PHN UG/L	ANC UG/L	FLU UG/L	PYR UG/L	BaA UG/L	CHR UG/L	BbF UG/L	BkF UG/L	BaP UG/L	INP UG/L	DaA UG/L	BgP UG/L	TOT UG/L
1	0.00	0.0	0.00	0.00	0.01	0.0	0.02	0.01	0.00	0.01	0.0	0.0	0.00	0.0	0.0	0.0	0.08
2	0.00	0.0	0.00	0.00	0.00	0.0	0.06	0.05	0.01	0.03	0.0	0.0	0.02	0.0	0.0	0.0	0.25
3	0.00	0.0	0.00	0.00	0.01	0.0	0.02	0.02	0.00	0.01	0.0	0.0	0.01	0.0	0.0	0.0	0.10
4a	0.00	0.0	0.00	0.00	0.02	0.0	0.04	0.04	0.01	0.04	0.0	0.1	0.02	0.0	0.0	0.0	0.31
4b	0.00	0.0	0.00	0.00	0.01	0.0	0.01	0.02	0.00	0.01	0.0	0.0	0.01	0.0	0.0	0.0	0.09
4c	0.00	0.0	0.00	0.00	0.01	0.0	0.01	0.01	0.00	0.01	0.0	0.0	0.01	0.0	0.0	0.0	0.11
4d	0.00	0.0	0.00	0.00	0.01	0.0	0.03	0.03	0.01	0.02	0.0	0.0	0.01	0.0	0.0	0.0	0.17
5	0.00	0.0	0.00	0.00	0.01	0.0	0.02	0.02	0.01	0.02	0.0	0.0	0.01	0.0	0.0	0.0	0.13
6	0.00	0.0	0.00	0.01	0.15	0.0	0.16	0.09	0.01	0.03	0.0	0.0	0.02	0.0	0.0	0.0	0.53
7	0.00	0.0	0.00	0.00	0.10	0.0	0.15	0.09	0.01	0.04	0.0	0.0	0.02	0.0	0.0	0.0	0.46
8	0.00	0.0	0.00	0.00	0.01	0.0	0.03	0.02	0.00	0.01	0.0	0.0	0.01	0.0	0.0	0.0	0.14
9	0.00	0.0	0.00	0.00	0.02	0.0	0.06	0.03	0.01	0.02	0.0	0.0	0.02	0.0	0.0	0.0	0.25
WTP	0.00	0.0	0.00	0.00	0.00	0.0	0.06	0.09	0.00	0.00	0.2	0.1	0.00	0.5	0.0	0.0	0.97
CKO	0.00	0.0	0.00	0.00	0.00	0.0	0.05	0.02	0.00	0.12	0.0	0.0	0.00	0.1	0.0	0.0	0.30
NFE																	
GTE	0.00	0.0	0.00	0.00	0.00	0.0	0.05	0.04	0.00	0.00	0.0	0.0	0.00	0.0	0.2	0.0	0.31

A-11

BLACKSTONE RIVER
OCTOBER 8, 1985
TOTALS

STATION	S.S. MG/L	HC UG/L	PAH UG/L	PHTHAL UG/L	COPROST UG/L	PCB NG/L
1	2.69	8.58	0.10	4.47	0.05	9.24
2	9.28	87.3	0.37	3.24	0.73	55.9
3	8.11	70.4	0.42	3.61	0.62	42.7
WOON	52.3	870	0.51	173	4.20	ND
4A	12.9	127	0.54	5.48	0.69	39.5
4B	10.4	91.8	0.56	4.42	0.49	26.1
4C	8.52	142	0.38	2.10	0.46	27.5
4D	6.51	56.6	0.27	3.46	0.32	24.0
5	10.8	91.9	0.45	2.94	0.76	33.3
NIFE	25.9	5.05	3.02	4.51	ND	ND
OKONITE	1.79	8.63	0.04	72.9	ND	ND
6	11.4	101	4.39	3.17	0.57	29.3
7	12.1	108	0.90	2.37	0.57	30.6
8	12.6	99.0	0.52	3.03	0.68	43.8
GTE	635	138	4.54	36.7	ND	5.94
9	13.3	129	0.57	3.18	0.55	43.1

ND = NONE DETECTED

A-12

SOLUBLE FRACTION BLACKSTONE RIVER OCTOBER 8,1985

STA.	S.S. MG/L	H.C. UG/L	PAH UG/L	COP UG/L	CHO UG/L	BBP UG/L	DHP UG/L	DOP UG/L	PHT UG/L	C1BZT UG/L	PCB NG/L
1	0.0	1.48	0.02	0.00	0.10	0.16	1.20	0.08	1.44	0.00	2.08
2	0.0	7.47	0.07	0.11	0.27	0.20	0.88	0.11	1.19	0.00	7.78
3	0.0	8.39	0.08	0.07	0.18	0.15	1.47	0.06	1.68	0.00	6.67
4a	0.0	16.8	0.05	0.00	1.27	0.92	2.12	0.00	3.01	0.00	3.16
4b	0.0	9.75	0.04	0.00	0.25	0.21	0.78	1.31	2.30	0.00	0.36
4c	0.0	11.8	0.05	0.00	0.26	0.18	1.16	0.03	1.37	0.00	3.52
4d	0.0	6.47	0.05	0.00	0.22	0.26	1.58	0.06	1.90	0.00	3.52
5	0.0	9.54	0.08	0.10	0.33	0.26	0.87	0.00	1.12	0.00	4.90
6	0.0	7.68	0.10	0.00	0.18	0.32	1.42	0.04	1.78	0.00	4.34
7	0.0	8.73	0.11	0.00	0.21	0.35	0.55	0.05	0.95	0.00	6.22
8	0.0	7.78	0.06	0.00	0.00	0.27	0.37	0.54	1.18	0.00	7.07
9	0.0	11.8	0.07	0.08	0.23	0.22	0.45	0.03	0.70	0.00	6.84
AVE.	0.0	8.97	0.06	0.03	0.29	0.29	1.07	0.19	1.55	0.00	4.71
WTP	0.0	23.8	0.05	0.00	0.00	1.58	53.4	0.00	55.0	0.00	0.00
OKO	0.0	0.54	0.01	0.00	0.00	0.64	17.6	0.37	18.6	0.00	0.00
NFE	0.0	5.05	2.83	0.00	0.00	1.28	1.80	0.00	3.08	0.00	0.00
GTE	0.0	3.33	0.34	0.00	0.00	0.50	1.31	0.08	1.89	0.00	0.00

SOLUBLE FRACTION BLACKSTONE RIVER OCTOBER 8, 1985

PAHS

STA.	NAP UG/L	ANT UG/L	ANE UG/L	FLO UG/L	PHN UG/L	ANC UG/L	FLU UG/L	PYR UG/L	BaA UG/L	CHR UG/L	BbF UG/L	BkF UG/L	BaP UG/L	INP UG/L	DaA UG/L	BgP UG/L	TOT UG/L
1	0.00	0.0	0.00	0.00	0.00	0.0	0.01	0.01	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.02
2	0.00	0.0	0.00	0.00	0.01	0.0	0.02	0.04	0.00	0.01	0.0	0.0	0.00	0.0	0.0	0.0	0.07
3	0.01	0.0	0.00	0.00	0.01	0.0	0.01	0.03	0.00	0.01	0.0	0.0	0.00	0.0	0.0	0.0	0.08
4a	0.00	0.0	0.00	0.00	0.00	0.0	0.01	0.03	0.00	0.01	0.0	0.0	0.00	0.0	0.0	0.0	0.05
4b	0.00	0.0	0.00	0.00	0.00	0.0	0.01	0.03	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.04
4c	0.00	0.0	0.00	0.00	0.00	0.0	0.01	0.03	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.05
4d	0.00	0.0	0.00	0.00	0.00	0.0	0.02	0.03	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.05
5	0.01	0.0	0.00	0.00	0.01	0.0	0.02	0.04	0.00	0.01	0.0	0.0	0.00	0.0	0.0	0.0	0.08
6	0.00	0.0	0.00	0.00	0.02	0.0	0.03	0.05	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.10
7	0.01	0.0	0.00	0.00	0.01	0.0	0.03	0.04	0.00	0.01	0.0	0.0	0.00	0.0	0.0	0.0	0.11
8	0.00	0.0	0.00	0.00	0.01	0.0	0.02	0.04	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.06
9	0.00	0.0	0.00	0.00	0.01	0.0	0.02	0.03	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.07
WTP	0.03	0.0	0.00	0.01	0.00	0.0	0.00	0.01	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.05
OKO	0.01	0.0	0.00	0.00	0.00	0.0	0.00	0.00	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.01
NFE	1.69	0.0	0.40	0.37	0.34	0.0	0.01	0.00	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	2.83
GTE	0.08	0.0	0.00	0.03	0.14	0.0	0.05	0.03	0.00	0.00	0.0	0.0	0.00	0.0	0.0	0.0	0.34

A-14

PARTICULATE FRACTION BLACKSTONE RIVER OCTOBER 8,1985

STA.	S.S. MG/L	H.C. UG/L	PAH UG/L	COP UG/L	CHO UG/L	BBP UG/L	DHP UG/L	DOP UG/L	PHT UG/L	C1BZT UG/L	PCB NG/L
1	2.69	7.10	0.08	0.05	1.02	0.36	2.31	0.36	3.03	0.00	7.16
2	9.28	79.8	0.30	0.62	0.78	0.13	1.55	0.38	2.05	0.00	48.1
3	8.11	62.0	0.34	0.55	0.70	0.17	1.23	0.53	1.93	0.00	35.9
4a	12.9	110	0.49	0.69	0.83	0.24	1.72	0.51	2.47	0.00	36.3
4b	10.4	82.0	0.52	0.49	0.56	0.06	1.68	0.38	2.12	0.00	25.7
4c	8.52	130	0.33	0.46	0.45	0.05	0.45	0.22	0.73	0.00	24.0
4d	6.51	50.1	0.22	0.32	0.60	0.08	1.37	0.11	1.56	0.00	20.5
5	10.8	82.4	0.37	0.66	1.13	0.15	1.49	0.19	1.82	0.00	28.4
6	11.4	92.9	4.29	0.57	0.70	0.10	0.95	0.35	1.39	0.00	25.0
7	12.1	99.7	0.79	0.57	0.81	0.11	1.11	0.20	1.42	0.00	24.4
8	12.6	91.2	0.46	0.68	1.17	0.12	1.38	0.35	1.85	0.00	36.7
9	13.3	117	0.50	0.47	0.74	0.39	1.88	0.21	2.48	0.00	36.3
AVE.	9.88	83.7	0.72	0.51	0.79	0.16	1.43	0.32	1.90	0.00	29.0
WTP	52.3	846	0.46	4.20	7.94	4.09	114	0.00	118	0.00	0.00
DKO	1.79	8.09	0.04	0.00	0.15	0.18	54.0	0.16	54.3	0.00	0.00
NFE	25.9	0.00	0.21	0.00	0.00	0.12	1.31	0.00	1.43	0.00	0.00
GTE	635	135	4.20	0.00	0.16	6.27	28.7	0.00	34.8	0.00	5.94

A-15

PARTICULATE FRACTION BLACKSTONE RIVER OCTOBER 8, 1985

PAHS

STA.	NAP UG/L	ANT UG/L	ANE UG/L	FLO UG/L	PHN UG/L	ANC UG/L	FLU UG/L	PYR UG/L	BaA UG/L	CHR UG/L	BbF UG/L	BkF UG/L	BaP UG/L	INP UG/L	DaA UG/L	BgP UG/L	TOT UG/L
1	0	0	0	0	0.01	0	0.017	0.012	0	0.007	0.014	0	0.01	0	0	0	0.08
2	0	0	0	0	0.02	0	0.033	0.046	0.02	0.034	0.044	0	0.03	0.02	0.013	0.03	0.3
3	0	0	0	0	0.03	0	0.046	0.046	0.02	0.036	0.07	0	0.03	0.03	0.007	0.03	0.34
4a	0	0	0	0	0.03	0	0.065	0.07	0.03	0.058	0.095	0	0.05	0.03	0.010	0.04	0.49
4b	0	0	0	0	0.02	0	0.05	0.055	0.04	0.056	0.118	0	0.06	0.05	0.014	0.05	0.52
4c	0	0	0	0	0.02	0	0.04	0.045	0.02	0.038	0.067	0	0.03	0.03	0.006	0.03	0.33
4d	0	0	0	0	0.02	0	0.027	0.032	0.01	0.024	0.038	0	0.02	0.01	0.014	0.02	0.22
5	0	0	0.01	0	0.02	0	0.049	0.067	0.03	0.047	0.062	0	0.03	0.02	0.006	0.02	0.37
6	0.04	0.01	0.06	0.1	1.48	0.01	1.202	0.708	0.04	0.228	0.163	0.1	0.11	0.04	0.005	0.04	4.29
7	0.01	0	0.01	.01	0.15	0.01	0.181	0.135	0.02	0.065	0.1	0	0.05	0.02	0.014	0.03	0.79
8	0	0	0	0	0.05	0	0.087	0.072	0.02	0.047	0.055	0	0.03	0.03	0.009	0.03	0.46
9	0	0	0	0	0.04	0.01	0.081	0.076	0.03	0.054	0.088	0	0.04	0.03	0.006	0.04	0.5
WTP	0	0	0	0	0.02	0	0.029	0.061	0.01	0.041	0.027	0	0.02	0	0.026	0.22	0.46
OKO	0	0	0	0	0	0	0.014	0.005	0	0.005	0.006	0	0	0	0	0	0.04
NFE	0	0	0	0	0	0	0.207	0	0	0	0	0	0	0	0	0	0.21
GTE	0	0	0.01	0	0.07	0.01	0.108	0.097	3.23	0.06	0.06	0	0.07	0.03	0.391	0.05	4.2

Blackstone River
Point Sources

I. Suspended Solids (MG/L)

station	7/8/85	8/20/85	10/8/85	x ± s.d.
Woon.	18.6	44.2	52.3	38.4 ± 17.6
Nife	NC	NC	25.9	25.9
Oko	0.40	0.54	1.79	0.91 ± 0.76
GTE	13.2	293	635	314 ± 311
x ± s.d.	10.7 ± 9.35	113 ± 158	179 ± 305	

II. Hydrocarbons (UG/L)

station	7/8/85	8/20/85	10/8/85	x ± s.d.
Woon	504	932	870	769 ± 231
Nife	NC	NC	5.05	5.05
Oko	14.2	16.2	8.63	13.0 ± 3.90
GTE	19.2	109	138	88.7 ± 62.0
x ± s.d.	179 ± 281	352 ± 504	255 ± 414	

III. Total PAH (UG/L)

station	7/8/85	8/20/85	10/8/85	x ± s.d.
Woon	0.20	1.07	0.51	0.59 ± 0.44
Nife	NC	NC	3.02	3.02
Oko	0.33	0.40	0.04	0.26 ± 0.19
GTE	0.58	1.12	4.54	2.08 ± 2.15
x ± s.d.	0.37 ± 0.19	0.86 ± 0.40	2.03 ± 2.12	

IV. Coprostenol (UG/L)

station	7/8/85	8/20/85	10/8/85	x ± s.d.
Woon	14.5	7.46	4.20	8.72 ± 5.26
Nife	NC	NC	ND	0.00
Oko	ND	ND	ND	0.00
GTE	ND	1.16	ND	1.16
x ± s.d.	14.5	4.31 ± 4.45	4.20	

V. Phthalates (UG/L)

station	7/8/85	8/20/85	10/8/85	x ± s.d.
Woon	250	169	173	197 ± 46
Nife	NC	NC	4.51	4.51
Oko	106	64.1	72.9	81.0 ± 22.0
GTE	2.12	97.6	36.7	45.5 ± 48.0
x ± s.d.	119 ± 124	110 ± 54	72 ± 73	

VI. PCB (NG/L)

station	7/8/85	8/20/85	10/8/85	x ± s.d.
Woon	ND	ND	ND	0.00
Nife	NC	NC	ND	0.00
Oko	ND	3.28	ND	1.09 ± 1.89
GTE	ND	37.0	5.94	14.3 ± 19.9
x ± s.d	0	20.1 ± 23.8	1.49 ± 2.97	

ND = None Detected NC = Not Collected

Blackstone River

I. Suspended Solids (MG/L)

station	7/8/85	8/20/85	10/8/85	x ± s.d.
1	1.96	3.34	2.69	2.66 ± 0.69
2	6.68	4.67	9.28	6.88 ± 2.31
3	4.80	7.01	8.11	6.64 ± 1.69
4	8.80	6.37	9.58	8.25 ± 1.67
5	8.09	6.50	10.8	8.46 ± 2.17
6	5.84	5.74	11.4	7.66 ± 3.24
7	5.09	4.91	12.1	7.37 ± 4.10
8	6.62	4.45	12.6	7.89 ± 4.22
9	8.38	6.46	13.3	9.38 ± 3.53
x ± s.d.	6.25 ± 2.14	5.49 ± 1.22	9.98 ± 3.21	

II. Hydrocarbons (UG/L)

station	7/8/85	8/20/85	10/8/85	x ± s.d.
1	15.7	11.5	8.58	11.9 ± 3.58
2	308	72.2	87.3	156 ± 132
3	30.3	43.5	70.4	48.1 ± 20.4
4	79.6	54.1	104	79.2 ± 24.9
5	55.3	54.6	91.9	67.3 ± 21.3
6	28.5	29.2	101	52.9 ± 41.7
7	26.5	24.8	108	53.1 ± 47.6
8	38.5	25.1	99.0	54.2 ± 39.4
9	87.2	59.1	129	91.8 ± 35.2
x ± s.d.	74.4 ± 91.0	41.6 ± 19.9	88.8 ± 34.0	

III. Total PAH (UG/L)

station	7/8/85	8/20/85	10/8/85	x ± s.d.
1	0.14	0.11	0.10	0.12 ± 0.02
2	0.42	0.33	0.37	0.37 ± 0.04
3	0.18	0.21	0.42	0.27 ± 0.13
4	0.28	0.30	0.44	0.34 ± 0.09
5	0.22	0.26	0.45	0.31 ± 0.12
6	0.75	0.67	4.39	1.94 ± 2.12
7	0.40	0.69	0.90	0.66 ± 0.25
8	0.35	0.22	0.52	0.36 ± 0.15
9	0.26	0.34	0.57	0.39 ± 0.16
x ± s.d.	0.33 ± 0.18	0.35 ± 0.20	0.91 ± 1.32	

IV. Phthalates (UG/L)

station	7/8/85	8/20/85	10/8/85	x ± s.d.
1	2.65	2.39	4.47	3.17 ± 1.13
2	13.6	3.88	3.24	6.91 ± 5.81
3	4.16	7.11	3.61	4.96 ± 1.88
4	12.8	1.71	3.87	6.13 ± 5.88
5	17.4	1.18	2.94	7.17 ± 8.90
6	3.45	15.3	3.17	7.31 ± 6.92
7	2.60	4.79	2.37	3.25 ± 1.34
8	5.00	1.45	3.03	3.16 ± 1.78
9	4.45	1.79	3.18	3.14 ± 1.33
x ± s.d.	7.35 ± 5.63	4.40 ± 4.52	3.32 ± 0.60	

V. Coprostanol (UG/L)

station	7/8/85	8/20/85	10/8/85	x ± s.d
1	0.14	0.14	0.05	0.11 ± 0.05
2	0.21	0.28	0.73	0.41 ± 0.28
3	0.09	0.14	0.62	0.28 ± 0.29
4	0.38	0.24	0.49	0.37 ± 0.12
5	0.31	0.16	0.76	0.41 ± 0.31
6	0.14	0.09	0.57	0.27 ± 0.26
7	0.06	0.07	0.57	0.23 ± 0.29
8	0	0.07	0.68	0.25 ± 0.37
9	0	0.15	0.55	0.23 ± 0.28
x ± s.d	0.15 ± 0.13	0.15 ± 0.07	0.56 ± 0.21	

VI. PCB (NG/L)

station	7/8/85	8/20/85	10/8/85	x ± s.d
1	4.28	5.10	9.24	6.21 ± 2.66
2	24.3	31.6	55.9	37.3 ± 16.5
3	8.25	29.1	42.7	26.7 ± 17.4
4	15.4	22.7	29.3	22.5 ± 6.95
5	13.[illegible]	21.7	33.3	22.7 ± 10.1
6	4.45	15.0	29.3	16.3 ± 12.5
7	6.27	19.1	30.6	18.7 ± 12.2
8	0	13.5	43.8	19.1 ± 22.4
9	18.8	22.4	43.1	28.1 ± 13.1
x ± s.d	10.5 ± 7.9	20.0 ± 8.10	35.2 ± 13.2	

Average total concentration of organics at each station in the Blackstone River (n = 3)

Station	River Mile	SS (MG/L)	Total HC (UG/L)	Total PAH (UG/L)	Phthalates (UG/L)	Coprostanol (UG/L)	PCB (NG/L)
1		2.66 ± 0.69	11.9 ± 3.58	0.12 ± 0.02	3.17 ± 1.13	0.11 ± 0.05	6.21 ± 2.6
2	0	6.88 ± 2.31	156 ± 132	0.37 ± 0.04	6.91 ± 5.81	0.41 ± 0.28	37.3 ± 16.
3	4.24	6.64 ± 1.69	48.1 ± 20.4	0.27 ± 0.13	4.96 ± 1.88	0.28 ± 0.29	26.7 ± 17.
4	7.08	8.25 ± 1.67	79.2 ± 24.9	0.34 ± 0.09	6.13 ± 5.88	0.37 ± 0.12	22.5 ± 6.9
5	8.78	8.46 ± 2.17	67.3 ± 21.3	0.31 ± 0.12	7.17 ± 8.90	0.41 ± 0.31	22.7 ± 10.
6	11.02	7.66 ± 3.24	52.9 ± 41.7	1.94 ± 2.12	7.31 ± 6.92	0.27 ± 0.26	16.3 ± 12
7	13.22	7.37 ± 4.10	53.1 ± 47.6	0.66 ± 0.25	3.25 ± 1.34	0.23 ± 0.29	18.7 ± 12.
8	14.82	7.89 ± 4.22	54.2 ± 39.4	0.36 ± 0.15	3.16 ± 1.78	0.25 ± 0.37	19.1 ± 22
9	16.78	9.38 ± 3.53	91.8 ± 35.2	0.39 ± 0.16	3.14 ± 1.33	0.23 ± 0.28	28.1 ± 13.

Appendix 3

Narragansett Bay Project
Historical Dataset Summary Sheet

NBP Index Number:

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1) Title: Hydrocarbons in river waters and point source effluents discharging into Narragansett Bay, and in the water column of the Providence River and upper bay.

2) Summary: See summary of published data.

3) Variables measured: Total hydrocarbons (ug/l), total and individual polycyclic aromatic hydrocarbons (ng/l) and total suspended solids (mg/l) in industrial and municipal effluents, and in river and bay water.

4) Sampling locations: Narragansett Bay watershed (see map for station locations).

5) Frequency of sampling: Water samples were collected from 11 point sources, 5 river mouths and 4 bay stations under dry weather conditions. The samples were collected on 4 different dates.

6) Time span of data: October 1985 to May 1986.

7) Principal Investigators:
   Name: James G. Quinn
   Organization: Graduate School of Oceanography
   Address: University of Rhode Island
   Narragansett, Rhode Island 02882
   Telephone: (401) 792-6219
   Funding: Narragansett Bay Project (URI # 5-39307).

8) Citation for published data:
   James G. Quinn, James S. Latimer, John T. Ellis, Lawrence A. LeBlanc and Jinshu Zheng, 1988.
   Analyses of archived water samples for organic pollutants.
   Final Report submitted to the Narragansett Bay Project Office.
   Graduate School of Oceanography, University of Rhode Island, 93 pp.

9) Location of original raw data: Room 130, Horn Laboratory, GSO/URI.

10) Person to contact for data: James G. Quinn

11) Are original data computerized: Yes

12) a. MacIntosh computer using MS Excell Word;
    b. Room 130, Horn Laboratory, GSO/URI;
    c. James G. Quinn.

13) Are summarized data computerized: Yes.

14) a. Summary statistics;
    b. MacIntosh computer using MS Excell;
    c. Room 130, Horn Laboratory, GSO/URI;
    d. James G. Quinn.

15) Data quality: See methods section of published data.

16) Not applicable.

17) Not applicable.

18) Form filled out by: James G. Quinn

19) Date: May 1988.

3-2 (cont'd)

Narragansett Bay

(water samples)

Station	41° N Latitude min	 sec	71° W Longitude min	 sec
2	48	48	23	54
4	43	35	21	40
7	38	00	22	18
12	38	58	15	53

Final Report
to the
Narragansett Bay Project Office

ANALYSES OF ARCHIVED WATER SAMPLES FOR ORGANIC POLLUTANTS

by

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James S. Latimer,
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May 1988

SUMMARY

The objective of this study was to provide information on the sources, magnitude and transport of selected organic pollutants in Narragansett Bay. Water samples were collected from 11 point sources (all but one were wastewater treatment facilities), 5 river mouths, and 4 bay stations at 4 different times - October 1985, November 1985, April 1986, and May 1986. The samples were filtered to separate particulate and dissolved components, and these two fractions were then analyzed for: polychlorinated biphenyls (PCBs), hexachlorocyclohexanes (HCHs), petroleum hydrocarbons (PHCs), polycyclic aromatic hydrocarbons (PAHs), substituted benzotriazoles (BZTs), phthalic acid esters, and the fecal sterol, coprostanol. Most of the compounds measured in this study showed a strong preference for the particulate phase; therefore, a much larger number of particulate samples were analyzed and only this data is reported in the results and discussion section. However, all of the data is reported in the appendices.

A statistical comparison of the 5 rivers was impossible because of the large standard deviations obtained on most of the analyses over the 4 different sampling dates. For example, the average concentrations of PCBs in the Woonasquatucket (25.3 ng/l) and Blackstone rivers (20.9 ng/l) were consistently higher than the other 3 rivers on all 4 dates; however, they were not statistically different than the other rivers. Nevertheless, the average values for PCBs in these two rivers exceeded the EPA water quality criteria for chronic toxicity in freshwater (14 ng/l). Taking into account the flow rates of the rivers over the course of the study, the Blackstone River was the largest single source of suspended solids (SS), PCBs, PHCs and the major phthalate-di(2-ethylhexyl-)phthalate (DEHP) to the bay; the Taunton River was the major source of most PAHs; and the Pawtuxet River was the largest contributor of coprostanol.

Several of the point sources exceeded the 50 mg/l limit on SS for municipal wastewater treatment facilities, especially the Newport, East Greenwich, Blackstone Valley and Bristol plants. Also, coprostanol levels at the Newport, Bristol, Quonset Point and East Greenwich plants were much higher than at the other facilities. Considering the flow rates of the various point sources, the Fields Point plant was the largest source of SS, PHCs, a major PAH - fluoranthene, and DEHP to the bay; the Blackstone Valley plant contributed the largest amount of PCBs; and the Newport plant was the major source of coprostanol.

In October 1985, the point sources were the major contributor of most components to the bay; and during November and April, the rivers usually contributed more fluoranthene, PHCs, PCBs and SS. In May 1986, the point sources were again the major supplier of most components. Overall, the point sources were the largest supplier of coprostanol, DEHP, PHCs and SS; and the rivers were the major source of fluoranthene and PCBs. The November values were the highest for SS, PCBs, fluoranthene and DEHP; and the May values showed the highest levels for PHCs and coprostanol. Based on this work, we estimate the following inputs into Narragansett Bay from combined rivers and point sources: 48 metric tons of SS/day; 72 grams of PCBs/day; 613 Kg of PHCs/day; 488 grams of fluoranthene/day; 14 Kg of DEHP/day and 39 Kg of coprostanol/day.

In the bay samples, the concentration of most components in surface waters was highest at Fox Point and decreased to the West Passage; however, in the case of DEHP and coprostanol, Conimicut Point had the highest concentration. For bottom waters, the highest values were usually observed at Conimicut Point, with the exception of DEHP and coprostanol where the concentrations were highest at Fox Point. In all cases, the observed concentrations were less than those reported for chronic toxicity in salt water.

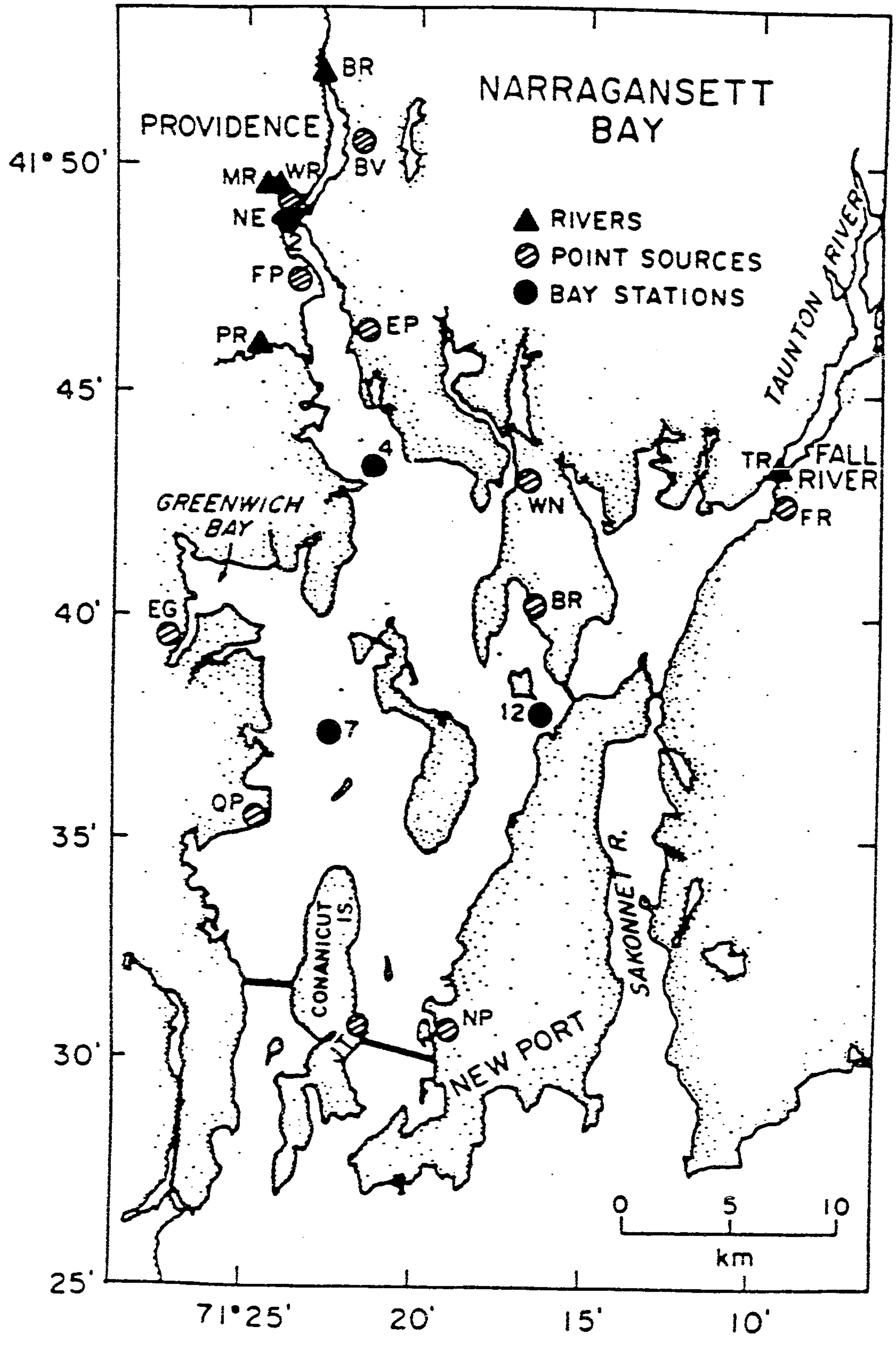

Figure II-1. Sampling locations for point source, river and Narragansett Bay water samples.

Table II-1. Rivers, point sources, and bay stations sampled in this study.

Rivers(5)

- Blackstone River (BR)
- Moshassuck River (MR)
- Pawtuxet River (PR)
- Taunton River (TR)
- Woonasquatucket River (WR)

Point Sources(11)--All but Narragansett Electric are WWTF.

- Blackstone Valley Plant (BV)
- Bristol Plant (BR)
- East Greenwich Plant (EG)
- East Providence Plant (EP)
- Fields Point Plant (FP)
- Fall River Plant (FR)
- Jamestown Plant (JT)
- Narragansett Electric Co. (NE)
- Newport Plant (NP)
- Quonset Point Plant (QP)
- Warren Plant (WN)

Bay(4)

- Station 2 - Fox Point
- Station 4 - Conimicut Point
- Station 7 - West Passage
- Station 12 - Hog Island

APPENDIX A.

Concentrations of components in rivers and point sources discharging into Narragansett Bay.

List of PCBs and PAHs

PCBs

IUPAC No.	Congener
101	2,2',4,5,5'-pentachlorobiphenyl
151	2,2',3,5,5',6-hexachlorobiphenyl
153	2,2',4,4',5,5'- "
138	2,2',3,4,4',5'- "
180	2,2',3,4,4',5,5'-heptachlorobiphenyl
170	2,2',3,3',4,4',5- "
201	2,2',3,3',4,5',6,6'-octachlorobiphenyl
195	2,2',3,3',4,4',5,6- "
194	2,2',3,3',4,4',5,5'- "
209	2,2',3,3',4,4',5,5',6,6'-decachlorobiphenyl

PAHs

Abbreviation	Compound
Nap	Naphthalene
AcL	Acenaphthylene
Acn	Acenaphthene
Flu	Fluorene
Phe	Phenanthrene
Ane	Anthracene
Flr	Fluoranthene
Pyr	Pyrene
BaA	Benzo(a)anthracene
Chr	Chrysene
B(b+k)F	Benzo(b+k)fluoranthene
BaP	Benzo(a)pyrene
InP	Indeno(1,2,3-cd)pyrene
DbA	Dibenzo(a,h)anthracene
Bpr	Benzo(ghi)perylene

Table A-1. Concentrations of organics in rivers and point sources discharging into Narragansett Bay (October 21-25, 1985).

RIVERS		SS (MG/L)	PCBs (NG/L) Ar 1242	Ar 1254	Ar 1260	Total
PAWTUXET	P	6.73	3.42	4.54	2.25	10.2
	S		N.D.	N.D.	N.D.	N.D.
MOSHASSUCK	P	2.94	2.56	3.54	2.00	8.10
WOONASQUATUCKET	P	9.34	7.89	19.5	13.4	40.8
	S		N.D.	N.D.	N.D.	N.D.
BLACKSTONE	P	4.52	3.47	8.55	5.88	17.9
	S		N.D.	1.16	N.D.	1.16
TAUNTON	P		N.D.	1.68	N.D.	1.68

POINT SOURCES		SS (MG/L)	PCBs (NG/L) Ar 1242	Ar 1254	Ar 1260	Total
BRISTOL	P	68.6	47.3	61.9	N.D.	109
BLACKSTONE VAL.	P	66.9	89.1	56.9	N.D.	146
	S		11.6	3.7	N.D.	15.3
EAST GREENWICH	P	51.9	41.5	43.4	N.D.	84.9
	S		N.D.	N.D.	N.D.	N.D.
EAST PROVIDENCE	P	10.3	N.D.	12.7	N.D.	12.7
FIELD'S POINT	P	61.6	N.D.	103	N.D.	103
	S		N.D.	N.D.	N.D.	N.D.
FALL RIVER	P	34.8	29.5	27.2	N.D.	56.7
NARR. ELECTRIC	P	11.1	N.D.	N.D.	N.D.	N.D.
NEWPORT	P	92.0	N.D.	39.4	N.D.	39.4
	S		N.D.	N.D.	N.D.	N.D.
WARREN	P	4.53	N.D.	5.27	N.D.	5.27
JAMESTOWN		N.C.	N.C.	N.C.	N.C.	N.C.
QUONSET POINT		N.C.	N.C.	N.C.	N.C.	N.C.

N.C.= Not collected P= Particulate S= Soluble
N.D.= Not detected

Table A-2. Concentrations of organics in rivers and point sources discharging into Narragansett Bay (October 21-25, 1985).

RIVERS		PCB Congeners (NG/L)									
		101	151	153	138	180	170	201	195	194	209
PAWTUXET	P	0.550	0.190	0.240	0.310	0.160	0.070	0.340	0.100	0.040	0.070
	S	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
MOSHASSUCK	P	0.410	0.130	0.190	0.270	0.150	0.080	0.260	0.100	0.040	0.030
WOONASQUATUCKET	P	2.34	0.940	2.09	2.55	1.46	0.860	0.700	0.120	0.220	0.060
	S	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
BLACKSTONE	P	0.820	0.310	0.520	0.670	0.520	0.230	0.490	0.130	0.140	0.070
	S	0.159	0.033	0.059	0.073	0.033	0.016	0.033	0.010	0.010	0.006
TAUNTON	P	0.170	0.060	0.110	0.130	0.100	0.030	0.180	0.060	0.030	0.030

POINT SOURCES		PCB Congeners (NG/L)									
		101	151	153	138	180	170	201	195	194	209
BRISTOL	P	8.15	1.91	3.34	4.30	1.30	0.660	0.973	N.D.	0.417	N.D.
BLACKSTONE VAL.	P	7.41	1.48	0.388	3.77	1.15	0.544	1.26	0.373	0.437	N.D.
	S	0.41	0.09	0.104	0.15	N.D.	0.018	0.08	0.024	0.020	N.D.
EAST GREENWICH	P	5.51	1.30	2.17	3.03	0.686	0.389	0.703	0.162	0.155	N.D.
	S	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
EAST PROVIDENCE	P	1.51	0.422	0.628	0.831	0.306	0.119	0.875	0.303	0.144	0.116
FIELD'S POINT	P	11.4	2.54	5.38	8.54	2.49	1.47	1.95	0.590	0.535	0.201
	S	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
FALL RIVER	P	3.70	0.892	1.26	1.54	N.D.	0.186	0.811	0.316	N.D.	0.357
NARR. ELECTRIC	P	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
NEWPORT	P	4.84	0.841	2.00	2.60	1.26	0.468	1.12	0.295	N.D.	N.D.
	S	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
WARREN	P	0.753	0.218	0.166	0.326	0.139	N.D.	0.626	0.229	N.D.	0.055
JAMESTOWN		N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.
QUONSET POINT		N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.

N.C.= Not collected P= Particulate S= Soluble
N.D.= Not detected

Table A-3. Concentrations of organics in rivers and point sources discharging into Narragansett Bay (October 21-25, 1985).

RIVERS		HCHs (NG/L)				Hydrocarbons (UG/L)		
		a	b	g	Total	F1-UCM	F1-RES	Tot F1
PAWTUXET	P	0.017	0.025	0.020	0.062	29.0	1.36	30.4
	S	N.D.	N.D.	6.050	6.050	1.85	0.12	1.97
MOSHASSUCK	P	N.D.	N.D.	N.D.	N.D.	12.6	1.32	13.9
WOONASQUATUCKET	P	0.031	N.D.	0.032	0.063	59.4	4.19	63.6
	S	0.140	N.D.	0.695	0.835	5.72	0.35	6.07
BLACKSTONE	P	N.D.	N.D.	N.D.	N.D.	43.8	1.26	45.1
	S	2.300	0.480	4.670	7.450	7.49	0.18	7.67
TAUNTON	P	N.D.	N.D.	N.D.	N.D.	4.68	0.75	5.43

POINT SOURCES		HCHs (NG/L)				Hydrocarbons (UG/L)		
		a	b	g	Total	F1-UCM	F1-RES	Tot F1
BRISTOL	P	77.3	N.D.	112	189	851	141	992
BLACKSTONE VAL.	P	N.D.	N.D.	N.D.	N.D.	705	41.6	747
	S	1.291	0.270	13.25	14.811	0.82	18.3	19.1
EAST GREENWICH	P	24.1	N.D.	53.5	77.6	1580	323	1900
	S	*	*	*	*	67.9	4.32	72.2
EAST PROVIDENCE	P	1.99	N.D.	6.94	8.93	52.0	4.38	56.4
FIELD'S POINT	P	6.44	N.D.	39.6	46.0	776	115.0	891
	S	N.D.	N.D.	23.4	23.4	87.4	10.0	97.4
FALL RIVER	P	N.D.	N.D.	N.D.	N.D.	834	46.1	880
NARR. ELECTRIC	P	N.D.	N.D.	N.D.	N.D.	6.07	0.22	6.29
NEWPORT	P	17.7	N.D.	N.D.	17.7	525	78.8	604
	S	N.D.	N.D.	8.25	8.25	12.0	1.74	13.7
WARREN	P	0.719	N.D.	N.D.	0.719	14.9	1.56	16.5
JAMESTOWN		N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.
QUONSET POINT		N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.

N.C.= Not collected   P= Particulate S= Soluble

N.D.= Not detected   *= Quantitation was not possible but g-HCH was detected.

TableA-4. Concentrations of organics in rivers and point sources discharging into Narragansett Bay (October 21-25, 1985).

RIVERS		PAHs (NG/L)														
		Nap	AcL	Acn	Flu	Phe	Ane	Flr	Pyr	BaA	Chr	B(b+k)F	BaP	InP	DbA	Bpr
PAWTUXET	P	3.61	N.D.	2.54	2.65	63.4	2.78	91.3	61.6	7.42	62.4	54.9	14.0	16.6	N.D.	21.7
	S	29.5	2.10	15.9	6.04	33.9	9.65	24.6	27.1	2.26	11.6	5.03	N.D.	N.D.	N.D.	N.D.
MOSHASSUCK	P	2.07	0.35	1.31	1.64	37.5	1.22	60.1	40.6	6.38	44.5	42.2	7.82	6.77	1.95	13.5
WOONASQUATUCKET	P	3.13	N.D.	2.32	3.15	67.4	3.22	124	83.1	14.6	89.1	74.8	19.9	14.2	4.35	41.7
	S	10.1	2.49	10.5	8.55	27.4	2.85	28.6	22.3	2.42	7.56	2.07	N.D.	N.D.	N.D.	N.D.
BLACKSTONE	P	4.47	N.D.	1.28	1.90	31.9	2.51	60.0	41.3	8.86	46.8	37.4	9.36	8.57	2.93	17.6
	S	18.6	1.90	6.10	6.62	18.1	4.47	28.0	24.8	2.79	11.8	9.32	1.56	0.87	N.D.	N.D.
TAUNTON	P	7.77	N.D.	6.19	7.19	246	4.48	343	221	19.6	132	146	24.6	20.6	5.02	26.7

POINT SOURCES		PAHs (NG/L)														
		Nap	AcL	Acn	Flu	Phe	Ane	Flr	Pyr	BaA	Chr	B(b+k)F	BaP	InP	DbA	Bpr
BRISTOL	P	N.D.	N.D.	N.D.	N.D.	244	N.D.	116	272	98.0	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
BLACKSTONE VAL.	P	18.6	N.D.	N.D.	N.D.	152	N.D.	265	339	118	163	181	N.D.	N.D.	N.D.	N.D.
	S	1042	N.D.	N.D.	N.D.	101	N.D.	80.3	46.7	N.D.	N.D.	62.3	N.D.	N.D.	N.D.	N.D.
EAST GREENWICH	P	N.D.	N.D.	13.7	N.D.	84.8	23.4	46.5	170	N.D.	102	41.7	N.D.	22.3	N.D.	N.D.
	S	37.5	N.D.	126	14.8	56.4	N.D.	16.0	52.7	12.3	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
EAST PROVIDENCE	P	N.D.	N.D.	N.D.	N.D.	5.30	N.D.	5.64	13.4	N.D.	4.55	N.D.	N.D.	N.D.	N.D.	N.D.
FIELDS POINT	P	N.D.	N.D.	N.D.	N.D.	45.2	N.D.	249	243	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	S	1975	N.D.	207	326	428	N.D.	65.4	68.5	8.25	21.8	N.D.	N.D.	N.D.	N.D.	N.D.
FALL RIVER	P	85.8	N.D.	N.D.	N.D.	80.8	N.D.	63.1	70.1	7.71	28.8	20.7	N.D.	N.D.	N.D.	N.D.
NARR. ELECTRIC	P	N.D.	N.D.	N.D.	N.D.	3.44	N.D.	10.6	5.11	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
NEWPORT	P	N.D.	N.D.	20.4	54.1	236	N.D.	216	179	N.D.	61.5	40.2	N.D.	148	N.D.	N.D.
	S	35.4	59.4	39.7	38.4	59.5	17.0	22.4	20.1	N.D.	7.14	N.D.	N.D.	N.D.	N.D.	N.D.
WARREN	P	N.D.	N.D.	N.D.	N.D.	3.28	N.D.	N.D.	9.47	N.D.	4.37	N.D.	N.D.	N.D.	N.D.	N.D.
JAMESTOWN		N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.
QUONSET POINT		N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.

N.C.= Not collected P= Particulate S= Soluble

N.D.= Not detected

TableA-5. Concentrations of organics in rivers and point sources discharging into Narragansett Bay (October 21-25, 1985).

RIVERS		BZTs (NG/L)				Phthalates (UG/L)			Sterols (UG/L)	
		C10	CL	C1	DBP	BBP	DEHP	DOP	Cop	Chol
PAWTUXET	P	17.4	3.05	N.D.	N.D.	N.D.	1.09	N.D.	1.46	2.52
	S	2.46	N.D.	890	N.D.	0.09	0.07	N.D.	0.09	0.21
MOSHASSUCK	P	N.D.	N.D.	N.D.	N.D.	0.12	4.59	0.14	1.24	2.36
WOONASQUATUCKET	P	N.D.	N.D.	N.D.	N.D.	1.55	3.09	N.D.	8.05	9.75
	S	N.D.	N.D.	N.D.	N.D.	0.11	1.18	N.D.	0.04	0.13
BLACKSTONE	P	N.D.	N.D.	N.D.	N.D.	N.D.	3.73	N.D.	1.93	3.69
	S	N.D.	N.D.	N.D.	N.D.	0.12	0.72	N.D.	0.07	0.16
TAUNTON	P	N.D.	N.D.	N.D.	N.D.	0.04	0.56	N.D.	0.07	0.8
POINT SOURCES		BZTs (NG/L)				Phthalates (UG/L)			Sterols (UG/L)	
		C10	CL	C1	DBP	BBP	DEHP	DOP	Cop	Chol
BRISTOL	P	N.D.	N.D.	N.D.	N.D.	N.D.	76.1	N.D.	672	574
BLACKSTONE VAL.	P	N.D.	N.D.	N.D.	N.D.	N.D.	20.1	8.04	22.8	111.0
	S	N.D.	N.D.	N.D.	N.D.	0.57	1.93	N.D.	1.41	2.51
EAST GREENWICH	P	N.D.	N.D.	N.D.	N.D.	N.D.	59.0	N.D.	175	182
	S	N.D.	N.D.	N.D.	N.D.	N.D.	6.30	N.D.	3.46	3.49
EAST PROVIDENCE	P	N.D.	N.D.	N.D.	N.D.	N.D.	2.00	N.D.	4.66	6.82
FIELD'S POINT	P	N.D.	N.D.	N.D.	N.D.	N.D.	18.0	N.D.	68.5	83.5
	S	N.D.	N.D.	N.D.	N.D.	1.53	5.03	N.D.	4.45	10.0
FALL RIVER	P	N.D.	N.D.	N.D.	N.D.	N.D.	11.9	3.83	18.1	35.0
NARR. ELECTRIC	P	N.D.	N.D.	N.D.	N.D.	N.D.	0.64	N.D.	N.D.	0.41
NEWPORT	P	N.D.	N.D.	N.D.	N.D.	N.D.	66.5	N.D.	468	488
	S	N.D.	N.D.	N.D.	N.D.	N.D.	9.11	N.D.	1.74	2.72
WARREN	P	N.D.	N.D.	N.D.	N.D.	N.D.	1.02	N.D.	1.62	2.56
JAMESTOWN		N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.
QUONSET POINT		N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.

N.C.= Not collected P= Particulate S= Soluble
N.D.= Not detected

TableA-6. Concentrations of organics in rivers and point sources discharging into Narragansett Bay (November 18-21, 1985).

RIVERS		SS (MG/L)	PCBs (NG/L)			
			Ar 1242	Ar 1254	Ar 1260	Total
PAWTUXET	P	8.08	N.D.	4.29	2.45	6.74
	S		N.D.	N.D.	N.D.	N.D.
MOSHASSUCK	P	4.09	N.D.	5.06	5.16	10.2
WOONASQUATUCKET	P	4.81	N.D.	6.60	5.07	11.7
BLACKSTONE	P	7.66	N.D.	11.6	13.4	25.0
	S		N.D.	N.D.	N.D.	N.D.
TAUNTON	P	3.99	N.D.	2.18	N.D.	2.18
	S		N.D.	N.D.	N.D.	N.D.

POINT SOURCES		SS (MG/L)	PCBs (NG/L)			
			Ar 1242	Ar 1254	Ar 1260	Total
BRISTOL	P	47.7	37.5	78.8	N.D.	116
BLACKSTONE VAL.	P	31.0	49.1	33.1	N.D.	82.2
	S		N.D.	N.D.	N.D.	N.D.
EAST GREENWICH	P	75.3	75.8	75.6	N.D.	151
	S		N.D.	N.D.	N.D.	N.D.
EAST PROVIDENCE	P	10.8	N.D.	9.05	N.D.	9.05
FIELD'S POINT	P	32.1	N.D.	66.2	N.D.	66.2
	S		N.D.	N.D.	N.D.	N.D.
FALL RIVER	P	14.8	N.D.	N.D.	N.D.	N.D.
NARR. ELECTRIC	P	1.87	N.D.	N.D.	N.D.	N.D.
NEWPORT	P	61.7	N.D.	50.4	N.D.	50.4
WARREN	P	37.1	N.D.	21.4	N.D.	21.4
JAMESTOWN	P	16.5	N.D.	22.3	N.D.	22.3
QUONSET POINT	P	42.4	N.D.	37.0	N.D.	37.0

P= Particulate S= Soluble

N.D.= Not detected

Table A-7 Concentrations of organics in rivers and point sources discharging into Narragansett Bay (November 18-21, 1985).

RIVERS		PCB Congeners (NG/L)									
		101	151	153	138	180	170	201	195	194	209
PAWTUXET	P	0.388	0.130	0.209	0.327	0.173	0.137	0.285	0.067	0.048	0.179
	S	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
MOSHASSUCK	P	0.520	0.223	0.444	0.647	0.295	0.278	0.274	0.038	0.107	0.069
WOONASQUATUCKET	P	0.781	0.263	0.554	0.843	0.536	0.282	0.352	0.127	0.103	0.115
BLACKSTONE	P	0.922	0.375	0.893	1.193	1.289	0.533	0.737	0.131	0.430	0.184
	S	0.245	0.054	0.078	0.086	0.051	0.024	0.036	0.010	0.014	0.006
TAUNTON	P	0.252	0.079	0.109	0.150	0.094	0.031	0.276	0.108	0.038	0.048
	S	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

POINT SOURCES		PCB Congeners (NG/L)									
		101	151	153	138	180	170	201	195	194	209
BRISTOL	P	6.57	1.54	1.72	3.39	0.537	0.471	0.564	0.293	0.233	N.D.
BLACKSTONE VAL.	P	2.54	0.487	0.622	1.42	N.D.	0.263	0.531	0.183	0.142	N.D.
	S	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
EAST GREENWICH	P	7.38	1.82	0.443	N.D.	0.770	0.498	1.11	0.378	0.241	N.D.
	S	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
EAST PROVIDENCE	P	0.979	0.299	0.370	0.634	0.312	0.148	0.679	0.237	0.130	N.D.
FIELD'S POINT	P	5.56	1.60	2.54	4.55	1.59	0.957	0.871	0.139	0.332	N.D.
	S	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
FALL RIVER	P	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
NARR. ELECTRIC	P	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
NEWPORT	P	5.41	N.D.	1.12	2.40	0.760	0.656	1.04	0.347	0.709	N.D.
WARREN	P	2.08	0.495	0.789	1.32	0.477	0.280	0.750	0.277	0.231	0.148
JAMESTOWN	P	2.50	N.D.	0.600	1.32	0.308	0.392	N.D.	N.D.	N.D.	N.D.
QUONSET POINT	P	3.06	0.966	1.24	2.02	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

P= Particulate S= Soluble

N.D.= Not detected

Table A-8. Concentrations of organics in rivers and point sources discharging into Narragansett Bay (November 18-21, 1985).

RIVERS		HCHs (NG/L)				Hydrocarbons (UG/L)		
		a	b	g	Total	F1-UCM	F1-RES	Tot F1
PAWTUXET	P	N.D.	N.D.	N.D.	N.D.	54.0	2.03	56.0
	S	0.182	0.130	1.299	1.611	4.21	0.99	5.20
MOSHASSUCK	P	N.D.	N.D.	N.D.	N.D.	19.8	1.64	21.4
WOONASQUATUCKET	P	0.014	N.D.	0.017	0.031	21.1	1.06	22.2
BLACKSTONE	P	N.D.	N.D.	N.D.	N.D.	57.5	1.56	59.1
	S	N.D.	N.D.	N.D.	N.D.	2.77	0.18	2.95
TAUNTON	P	0.420	N.D.	N.D.	0.420	6.00	0.38	6.38
	S	0.786	N.D.	0.610	1.40	0.56	0.23	0.79

POINT SOURCES		HCHs (NG/L)				Hydrocarbons (UG/L)		
		a	b	g	Total	F1-UCM	F1-RES	Tot F1
BRISTOL	P	N.D.	N.D.	N.D.	N.D.	449	51.4	500
BLACKSTONE VAL.	P	N.D.	N.D.	1.36	1.36	460	24.9	485
	S	0.334	0.276	5.94	6.55	4.33	2.5	6.83
EAST GREENWICH	P	N.D.	N.D.	N.D.	N.D.	1930	86.1	2016
	S	0.679	N.D.	3.80	4.48	128	6.86	135
EAST PROVIDENCE	P	N.D.	N.D.	N.D.	N.D.	50.1	3.91	54.0
FIELD'S POINT	P	N.D.	N.D.	N.D.	N.D.	794	30.2	824
	S	N.D.	N.D.	19.7	19.7	49.4	5.20	54.6
FALL RIVER	P	N.D.	N.D.	N.D.	N.D.	321	18.3	339
NARR. ELECTRIC	P	N.D.	N.D.	N.D.	N.D.	4.05	0.60	4.65
NEWPORT	P	N.D.	N.D.	N.D.	N.D.	393	57.0	450
WARREN	P	0.056	N.D.	0.296	0.352	242	13.8	256
JAMESTOWN	P	N.D.	N.D.	N.D.	N.D.	97.3	7.52	105
QUONSET POINT	P	N.D.	N.D.	N.D.	N.D.	355	33.1	388

P= Particulate S= Soluble

N.D.= Not detected

Table A-9. Concentrations of organics in rivers and point sources discharging into Narragansett Bay (November 18-21, 1985).

RIVERS		PAHs (NG/L)														
		Nap	AcL	Acn	Flu	Phe	Ane	Flr	Pyr	BaA	Chr	B(b+k)F	BaP	InP	DbA	Bpr
PAWTUXET	P	1.36	1.15	1.26	N.D.	12.0	1.24	40.5	35.8	23.9	34.6	51.7	8.90	10.8	3.85	28.3
	S	N.D	N.D	N.D	N.D	30.0	N.D	42.4	33.7	N.D	9.7	19.20	N.D	N.D	N.D	N.D
MOSHASSUCK	P	3.89	N.D.	N.D.	N.D.	6.70	N.D.	21.8	20.1	7.07	16.8	26.2	10.1	8.88	4.22	14.7
WOONASQUATUCKET	P	1.74	N.D.	N.D.	N.D.	7.06	1.11	21.6	18.0	8.17	17.1	24.9	4.33	7.70	2.62	25.2
BLACKSTONE	P	2.90	2.75	1.42	1.91	22.8	3.62	60.2	50.7	19.2	53.3	91.2	31.8	32.4	20.8	71.9
	S	2.6	N.D.	N.D.	N.D.	12.7	N.D.	22.3	28.8	1.62	10.0	11.20	N.D.	N.D.	N.D.	N.D.
TAUNTON	P	1.32	N.D.	4.85	6.58	368	7.25	629	418	54.4	272	358	69.8	63.2	28.0	86.3
	S	93.4	N.D.	46.7	37.4	761	10.5	591	370	17.0	81.6	32.4	3.79	1.80	N.D.	2.94

POINT SOURCES		PAHs (NG/L)														
		Nap	AcL	Acn	Flu	Phe	Ane	Flr	Pyr	BaA	Chr	B(b+k)F	BaP	InP	DbA	Bpr
BRISTOL	P	8.71	N.D.	N.D.	N.D.	75.5	N.D.	52.8	105	41.5	19.6	27.9	N.D.	N.D.	N.D.	N.D.
BLACKSTONE VAL.	P	8.80	N.D.	N.D.	N.D.	51.6	N.D.	92.9	120	46.7	67.1	38.4	N.D.	7.90	N.D.	N.D.
	S	65.3	N.D.	N.D	N.D.	N.D.	N.D.	31.5	33.2	N.D.	110	261	N.D.	N.D.	N.D.	N.D.
EAST GREENWICH	P	0.00	N.D.	N.D.	N.D.	161	N.D.	130	369	29.3	54.7	65.4	N.D.	74.7	N.D.	N.D.
	S	208	N.D.	102	33.7	143	23.3	35.3	60.4	14.7	10.2	N.D.	N.D.	N.D.	N.D.	N.D.
EAST PROVIDENCE	P	2.79	N.D.	N.D.	N.D.	5.87	N.D.	4.28	10.7	3.82	6.35	5.10	N.D.	N.D.	N.D.	N.D.
FIELDS POINT	P	0.00	N.D.	N.D.	N.D.	62.9	N.D.	102	188	0.00	31.1	45.5	N.D.	N.D.	N.D.	N.D.
	S	225	N.D.	N.D.	80.5	121	N.D.	33.4	51.7	N.D.	12.0	N.D.	N.D.	N.D.	N.D.	N.D.
FALL RIVER	P	151	N.D.	N.D.	11.5	83.9	N.D.	42.1	71.9	0.00	14.4	11.3	N.D.	N.D.	N.D.	N.D.
NARR. ELECTRIC	P	0.30	N.D.	0.96	0.76	5.92	0.87	10.1	10.2	3.47	15.4	10.1	N.D.	4.33	N.D.	N.D.
NEWPORT	P	4.97	N.D.	10.2	20.1	192	N.D.	138	154	74.5	64.7	0.00	N.D.	N.D.	N.D.	N.D.
WARREN	P	17.9	N.D.	N.D.	N.D.	46.0	N.D.	50.9	93.3	14.9	36.5	72.8	N.D.	N.D.	N.D.	N.D.
JAMESTOWN	P	6.04	N.D.	N.D.	N.D.	69.4	N.D.	73.0	91.7	16.5	22.5	32.3	19.9	12.3	N.D.	N.D.
QUONSET POINT	P	10.6	N.D.	N.D.	N.D.	87.7	N.D.	112	113	43.8	52.6	39.9	N.D.	N.D.	N.D.	N.D.

P= Particulate S= Soluble

N.D.= Not detected

Table A-10. Concentrations of organics in rivers and point sources discharging into Narragansett Bay (November 18-21, 1985).

RIVERS		BZTs (NG/L)			Phthalates (UG/L)				Sterols (UG/L)
		C10	CL	C1	DBP	BBP	DEHP	DOP	Cop
PAWTUXET	P	18.0	1.71	700	N.D.	N.D.	3.13	N.D.	2.22
	S	N.D.	N.D.	5310	N.D.	N.D.	0.34	1.09	0.12
MOSHASSUCK	P	N.D.	N.D.	190	N.D.	N.D.	1.56	N.D.	2.63
WOONASQUATUCKET	P	N.D.	N.D.	N.D.	N.D.	1.73	0.61	0.22	2.10
BLACKSTONE	P	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.04
	S	N.D.	N.D.	N.D.	N.D.	0.26	2.60	5.03	0.53
TAUNTON	P	N.D.	N.D.	N.D.	N.D.	0.12	5.14	N.D.	0.30
	S	N.D.	N.D.	N.D.	N.D.	0.04	0.85	0.24	N.D.

POINT SOURCES		BZTs (NG/L)			Phthalates (UG/L)				Sterols (UG/L)
		C10	CL	C1	DBP	BBP	DEHP	DOP	Cop
BRISTOL	P	N.D.	N.D.	N.D.	N.D.	56.7	72.0	N.D.	281
BLACKSTONE VAL.	P	N.D.	N.D.	N.D.	N.D.	5.38	29.9	2.17	22.3
	S	N.D.	N.D.	N.D.	N.D.	0.07	0.06	N.D.	0.06
EAST GREENWICH	P	N.D.	N.D.	N.D.	N.D.	59.1	72.4	N.D.	137
	S	N.D.	N.D.	N.D.	N.D.	0.69	4.79	0.67	1.53
EAST PROVIDENCE	P	N.D.	N.D.	1220	N.D.	N.D.	37.4	0.14	5.33
FIELD'S POINT	P	N.D.	N.D.	N.D.	N.D.	9.34	48.4	N.D.	32.6
	S	N.D.	N.D.	N.D.	N.D.	2.28	3.12	2.11	0.46
FALL RIVER	P	N.D.	N.D.	N.D.	N.D.	5.07	16.0	N.D.	11.3
NARR. ELECTRIC	P	N.D.	N.D.	150	N.D.	0.17	21.3	N.D.	0.49
NEWPORT	P	N.D.	N.D.	N.D.	N.D.	90.6	44.7	N.D.	355
WARREN	P	N.D.	N.D.	N.D.	N.D.	7.18	24.6	0.45	27.7
JAMESTOWN	P	N.D.	N.D.	N.D.	N.D.	N.D.	7.45	N.D.	7.69
QUONSET POINT	P	N.D.	N.D.	N.D.	N.D.	N.D.	40.5	N.D.	171

P= Particulate S= Soluble

N.D.= Not detected

Table A-11. Concentrations of organics in rivers and point sources discharging into Narragansett Bay (April 7-10, 1986).

RIVERS		SS (MG/L)	PCBs (NG/L)			
			Ar 1242	Ar 1254	Ar 1260	Total
PAWTUXET	P	7.25	N.D.	3.23	1.46	4.69
	S		N.D.	N.D.	N.D.	N.D.
MOSHASSUCK	P	13.20	N.D.	13.6	N.D.	13.6
	S		28.6	11.6	N.D.	40.2
WOONASQUATUCKET	P	9.79	N.D.	13.80	7.01	20.8
BLACKSTONE	P	4.31	N.D.	4.86	5.37	10.2
	S		0.35	0.25	N.D.	0.60
TAUNTON	P	5.50	N.D.	3.08	N.D.	3.08
	S		N.D.	N.D.	N.D.	N.D.

POINT SOURCES		SS (MG/L)	PCBs (NG/L)			
			Ar 1242	Ar 1254	Ar 1260	Total
BRISTOL	P	47.50	N.D.	47.2	N.D.	47.2
BLACKSTONE VAL.	P	40.00	N.D.	37.8	N.D.	37.8
	S		8.90	N.D.	N.D.	8.90
EAST GREENWICH	P	134.00	N.D.	64.0	N.D.	64.0
EAST PROVIDENCE	P	12.50	N.D.	11.3	N.D.	11.3
FIELD'S POINT	P	30.00	N.D.	N.D.	N.D.	N.D.
	S		N.D.	N.D.	N.D.	N.D.
FALL RIVER	P	23.90	N.D.	N.D.	N.D.	N.D.
	S		N.D.	N.D.	N.D.	N.D.
NARR. ELECTRIC	P	2.38	N.D.	4.40	N.D.	4.40
NEWPORT	P	71.90	N.D.	N.D.	N.D.	N.D.
WARREN	P	42.20	N.D.	N.D.	N.D.	N.D.
JAMESTOWN	P	6.42	N.D.	4.72	N.D.	4.72
QUONSET POINT	P	56.30	N.D.	70.0	N.D.	70.0

P= Particulate S= Soluble

N.D.= Not detected

Table A-12 Concentrations of organics in rivers and point sources discharging into Narragansett Bay (April 7-10, 1986).

RIVERS		PCB Congeners (NG/L)									
		101	151	153	138	180	170	201	195	194	209
PAWTUXET	P	0.667	0.206	0.000	0.153	0.586	0.142	0.338	0.144	0.060	0.104
	S	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
MOSHASSUCK	P	0.827	0.253	0.477	0.918	0.466	0.545	0.309	0.104	0.128	0.153
	S	1.847	0.641	0.552	0.718	0.204	N.D.	N.D.	N.D.	N.D.	N.D.
WOONASQUATUCKET	P	1.145	0.319	0.762	1.199	0.698	0.371	0.403	0.122	0.126	0.102
BLACKSTONE	P	0.415	0.208	0.362	0.504	0.497	0.190	0.473	0.151	0.199	0.078
	S	0.031	0.007	0.013	0.014	0.008	0.003	0.006	0.002	0.003	0.002
TAUNTON	P	0.373	N.D.	N.D.	N.D.	0.377	0.092	0.194	0.092	0.036	0.067
	S	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

POINT SOURCES		PCB Congeners (NG/L)									
		101	151	153	138	180	170	201	195	194	209
BRISTOL	P	5.278	2.582	N.D.	1.966	N.D.	N.D.	1.139	N.D.	N.D.	N.D.
BLACKSTONE VAL.	P	8.145	N.D.	N.D.	N.D.	3.284	N.D.	N.D.	N.D.	N.D.	N.D.
	S	0.230	N.D.	0.313	0.236	0.237	0.067	0.277	0.029	0.034	N.D.
EAST GREENWICH	P	6.201	1.845	3.660	5.228	1.729	0.797	2.289	N.D.	N.D.	N.D.
EAST PROVIDENCE	P	1.172	0.391	0.570	0.761	0.393	0.134	0.909	0.293	0.141	0.079
FIELD'S POINT	P	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	S	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
FALL RIVER	P	1.602	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	S	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
NARR. ELECTRIC	P	0.420	0.142	0.227	0.348	0.258	0.084	0.434	0.140	0.064	0.049
NEWPORT	P	N.D.	N.D.	N.D.	N.D.	4.622	N.D.	N.D.	N.D.	N.D.	N.D.
WARREN	P	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
JAMESTOWN	P	0.429	0.163	0.248	0.344	0.170	0.055	0.274	0.090	0.058	N.D.
QUONSET POINT	P	6.862	4.966	3.547	17.857	2.344	1.015	2.084	N.D.	N.D.	N.D.

P= Particulate S= Soluble

N.D.= Not detected

Table A-13 Concentrations of organics in rivers and point sources discharging into Narragansett Bay (April 7-10, 1986).

RIVERS		HCHs (NG/L)				Hydrocarbons (UG/L)		
		a	b	g	Total	F1-UCM	F1-RES	Tot F1
PAWTUXET	P	N/A	N/A	N/A	N/A	64.3	3.90	68.2
	S	0.587	N.D.	1.219	1.806	1.89	0.12	2.01
MOSHASSUCK	P	N/A	N/A	N/A	N/A	180	7.70	188
	S	0.547	N.D.	0.210	0.757	4.21	0.44	4.66
WOONASQUATUCKET	P	N/A	N/A	N/A	N/A	135	5.55	141
BLACKSTONE	P	N/A	N/A	N/A	N/A	34.9	1.89	36.8
	S	N/A	N/A	N/A	N/A	2.05	0.06	2.11
TAUNTON	P	N/A	N/A	N/A	N/A	22.6	1.44	24.0
	S	0.382	N.D.	0.611	0.993	0.20	1.75	1.94

POINT SOURCES		HCHs (NG/L)				Hydrocarbons (UG/L)		
		a	b	g	Total	F1-UCM	F1-RES	Tot F1
BRISTOL	P	N/A	N/A	N/A	N/A	660	108.2	768
BLACKSTONE VAL.	P	N/A	N/A	N/A	N/A	435	24.6	459
	S	N.D.	N.D.	2.932	2.932	26.7	N.D.	26.7
EAST GREENWICH	P	N/A	N/A	N/A	N/A	4142	176.0	4318
EAST PROVIDENCE	P	N/A	N/A	N/A	N/A	113	3.65	116
FIELD'S POINT	P	N/A	N/A	N/A	N/A	751	38.8	790
	S	N.D.	N.D.	3.150	3.150	41.9	12.1	54.1
FALL RIVER	P	N/A	N/A	N/A	N/A	361	21.0	382
	S	0.556	N.D.	3.318	3.874	100	15.70	115
NARR. ELECTRIC	P	N/A	N/A	N/A	N/A	12.1	1.70	13.8
NEWPORT	P	N/A	N/A	N/A	N/A	533	78.4	611
WARREN	P	N/A	N/A	N/A	N/A	230	16.0	246
JAMESTOWN	P	N/A	N/A	N/A	N/A	35.2	1.64	36.9
QUONSET POINT	P	N/A	N/A	N/A	N/A	610	43.1	653

P= Particulate S= Soluble

N.D.= Not detected N/A= Not analyzed

Table A-14 Concentrations of organics in rivers and point sources discharging into Narragansett Bay (April 7-10, 1986).

RIVERS		PAHs (NG/L)														
		Nap	AcL	Acn	Flu	Phe	Ane	Flr	Pyr	BaA	Chr	B(b+k)F	BaP	InP	DbA	Bpr
PAWTUXET	P	1.80	N.D.	1.52	1.88	28.6	3.41	54.5	49.7	17.4	35.3	43.0	13.8	13.8	5.02	25.9
	S	65.1	N.D.	N.D.	25.4	64.4	N.D.	31.8	27.1	N.D.	N.D.	N.D.	N.D.	1.40	N.D.	N.D.
MOSHASSUCK	P	8.06	N.D.	7.5	8.47	119	12.9	251	219	85.0	122	174	64.2	47.0	14.3	71.1
	S	7.88	N.D.	11.9	14.4	33.8	5.41	63.8	54.4	2.9	10.8	6.63	N.D.	N.D.	N.D.	N.D.
WOONASQUATUCKET	P	4.32	2.49	4.11	4.31	62.9	7.65	157	119	57.5	74.9	129.0	49.5	48.8	13.2	29.1
BLACKSTONE	P	2.28	N.D.	N.D.	1.62	16.2	2.95	29.7	28.1	12.3	19.6	25.1	9.61	7.11	2.64	12.4
	S	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	10.8	17.2	N.D.	11.2	N.D.	N.D.	N.D.	N.D.	N.D.
TAUNTON	P	N.D.	N.D.	N.D.	1.36	13.9	N.D.	28.9	24.3	10.3	15.1	21.3	6.60	6.74	2.75	13.4
	S	21.4	N.D.	15.2	5.9	9.7	N.D.	11.2	13.9	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

POINT SOURCES		PAHs (NG/L)														
		Nap	AcL	Acn	Flu	Phe	Ane	Flr	Pyr	BaA	Chr	B(b+k)F	BaP	InP	DbA	Bpr
BRISTOL	P	N.D.	N.D.	N.D.	N.D.	85.0	N.D.	97.4	122	72.5	104	32.1	N.D.	9.24	N.D.	N.D.
BLACKSTONE VAL.	P	7.79	N.D.	N.D.	N.D.	31.6	N.D.	99.2	93.2	21.4	49.3	54.0	25.8	15.3	N.D.	N.D.
	S	58.8	N.D.	N.D.	N.D.	44.9	N.D.	57.4	66.1	N.D.	N.D.	458	N.D.	N.D.	N.D.	N.D.
EAST GREENWICH	P	23.7	N.D.	32.5	N.D.	294	N.D.	189	282	93.8	103	158	N.D.	48.8	N.D.	N.D.
EAST PROVIDENCE	P	4.1	N.D.	N.D.	N.D.	11.3	N.D.	25.3	29.1	3.82	19.7	31.0	N.D.	5.11	N.D.	N.D.
FIELDS POINT	P	12.2	N.D.	N.D.	N.D.	253	N.D.	220	208	38.0	94.3	68.4	26.7	21.5	N.D.	N.D.
	S	1339	N.D.	655	813	816	90.6	152	99.0	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
FALL RIVER	P	296	N.D.	9.26	27.0	109	13.5	60.8	65.8	22.6	34.7	38.1	19.0	29.4	N.D.	N.D.
	S	2840	N.D.	250	321	398	113	71.1	66.1	35.8	N.D.	55.4	N.D.	N.D.	N.D.	N.D.
NARR. ELECTRIC	P	N.D.	N.D.	1.52	N.D.	6.74	N.D.	10.3	12.0	N.D.	4.32	3.64	N.D.	N.D.	N.D.	N.D.
NEWPORT	P	5.16	N.D.	5.31	11.7	101	11.5	73.2	86.7	108	49.5	N.D.	N.D.	N.D.	N.D.	N.D.
WARREN	P	54.8	N.D.	N.D.	N.D.	127	10.7	84.1	88.2	N.D.	23.8	44.5	N.D.	N.D.	N.D.	N.D.
JAMESTOWN	P	2.29	N.D.	N.D.	N.D.	34.2	N.D.	47.2	38.0	8.05	36.8	51.9	N.D.	N.D.	N.D.	N.D.
QUONSET POINT	P	12.5	N.D.	N.D.	12.2	130	N.D.	893	236	65.5	85.9	122	62.1	39.2	N.D.	N.D.

P= Particulate S= Soluble

N.D.= Not detected

TableA-15 Concentrations of organics in rivers and point sources discharging into Narragansett Bay (April 7-10, 1986).

RIVERS		BZTs (NG/L)			Phthalates (UG/L)				Sterols (UG/L)
		C10	CL	C1	DBP	BBP	DEHP	DOP	Cop
PAWTUXET	P	N.D.	N.D.	N.D.	N.D.	0.07	0.37	N.D.	5.96
	S	N.D.	N.D.	N.D.	N.D.	0.24	0.21	0.08	0.28
MOSHASSUCK	P	N.D.	N.D.	N.D.	N.D.	N.D.	0.43	N.D.	1.06
	S	N.D.	N.D.	N.D.	N.D.	0.18	0.21	N.D.	0.10
WOONASQUATUCKET	P	N.D.	N.D.	N.D.	N.D.	0.06	0.50	N.D.	3.63
BLACKSTONE	P	N.D.	N.D.	N.D.	N.D.	N.D.	0.37	N.D.	0.61
	S	N.D.	N.D.	N.D.	N.D.	0.12	0.37	N.D.	0.07
TAUNTON	P	N.D.	N.D.	N.D.	N.D.	N.D.	0.15	N.D.	0.53
	S	N.D.	N.D.	N.D.	N.D.	0.06	0.22	0.20	0.14

POINT SOURCES		BZTs (NG/L)			Phthalates (UG/L)				Sterols (UG/L)
		C10	CL	C1	DBP	BBP	DEHP	DOP	Cop
BRISTOL	P	N.D.	N.D.	N.D.	N.D.	10.8	5.97	2.39	106
BLACKSTONE VAL.	P	N.D.	N.D.	N.D.	N.D.	2.35	2.32	0.56	6.08
	S	N.D.	N.D.	N.D.	N.D.	2.34	3.60	0.94	1.37
EAST GREENWICH	P	N.D.	N.D.	N.D.	N.D.	N.D.	23.6	N.D.	101
EAST PROVIDENCE	P	N.D.	N.D.	N.D.	N.D.	0.19	0.18	N.D.	5.28
FIELD'S POINT	P	N.D.	N.D.	N.D.	N.D.	1.23	1.84	3.07	15.3
	S	N.D.	N.D.	N.D.	N.D.	8.29	2.81	N.D.	2.92
FALL RIVER	P	N.D.	N.D.	N.D.	N.D.	1.87	4.67	N.D.	11.0
	S	N.D.	N.D.	N.D.	N.D.	1.24	1.96	N.D.	1.82
NARR. ELECTRIC	P	N.D.	N.D.	N.D.	1.79	N.D.	14.2	N.D.	0.30
NEWPORT	P	N.D.	N.D.	N.D.	N.D.	3.54	18.98	N.D.	133
WARREN	P	N.D.	N.D.	N.D.	N.D.	N.D.	1.84	N.D.	16.7
JAMESTOWN	P	N.D.	N.D.	360	N.D.	0.14	0.23	N.D.	3.55
QUONSET POINT	P	N.D.	N.D.	N.D.	N.D.	4.03	2.99	N.D.	126

P= Particulate S= Soluble

N.D.= Not detected

Table A-16 Concentrations of organics in rivers and point sources discharging into Narragansett Bay (May 19-22, 1986).

RIVERS		SS	PCBs (NG/L)			
		(MG/L)	Ar 1242	Ar 1254	Ar 1260	Total
PAWTUXET A-C	P	5.89	N.D.	5.51	N.D.	5.51
	S		0.46	N.D.	N.D.	0.46
PAWTUXET D	P	67.6	30.1	66.7	27.4	124
	S		N.D.	N.D.	N.D.	N.D.
MOSHASSUCK A-C	P	7.23	4.38	9.54	N.D.	13.9
MOSHASSUCK D	P	88.1	52.9	179	179	410
WOONASQUA A-C	P	7.82	4.57	12.5	10.6	27.7
WOONASQUA D	P	45.0	5.37	15.6	9.94	30.9
BLACKSTONE A-C	P	6.89	5.48	16.7	8.34	30.5
	S		0.30	0.54	N.D.	0.84
BLACKSTONE D	P	13.8	N.D.	20.9	N.D.	20.9
	S		0.68	0.46	N.D.	1.14
TAUNTON	P	6.12	2.16	3.28	N.D.	5.44

POINT SOURCES		SS	PCBs (NG/L)			
		(MG/L)	Ar 1242	Ar 1254	Ar 1260	Total
BRISTOL	P	80.8	N.D.	60.9	N.D.	61
BLACKSTONE VAL.	P	109	112	74.9	N.D.	187
	S		N.D.	N.D.	N.D.	N.D.
EAST GREENWICH	P	78.7	N.D.	N.D.	N.D.	N.D.
	S		N.D.	N.D.	N.D.	N.D.
EAST PROVIDENCE	P	20.0	N.D.	15.0	N.D.	15.0
FIELD'S POINT	P	59.2	-	-	-	-
	S		N.D.	N.D.	N.D.	N.D.
FALL RIVER	P	34.4	N.D.	N.D.	N.D.	N.D.
NARR. ELECTRIC	P	5.77	3.22	7.86	N.D.	11.1
NEWPORT	P	145	N.D.	65.0	N.D.	65.0
WARREN	P	58.9	N.D.	39.1	N.D.	39.1
JAMESTOWN	P	9.36	N.D.	10.6	N.D.	10.6
QUONSET POINT	P	67.7	94.1	104	N.D.	198

- = Sample lost   P= Particulate S= Soluble
N.D.= Not detected

Table A-17 Concentrations of organics in rivers and point sources discharging into Narragansett Bay (May 19-22, 1986).

RIVERS		PCB Congeners (NG/L)									
		101	151	153	138	180	170	201	195	194	209
PAWTUXET A-C	P	0.425	0.158	0.229	0.318	0.137	0.067	0.257	0.094	0.051	0.092
	S	0.031	0.006	0.006	0.009	0.001	N.D.	0.001	N.D.	N.D.	N.D.
PAWTUXET D	P	4.682	1.874	2.835	4.086	2.691	1.350	1.795	0.617	0.570	1.067
	S	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
MOSHASSUCK A-C	P	0.887	0.305	0.479	0.687	0.137	0.139	0.367	0.113	0.072	0.055
MOSHASSUCK D	P	15.881	4.552	7.492	12.264	3.140	2.174	2.023	0.528	0.681	0.741
WOONASQUA A-C	P	1.319	0.629	1.257	1.633	0.930	0.548	0.496	0.144	0.157	0.088
WOONASQUA D	P	1.377	0.513	1.164	1.595	0.805	0.508	0.308	0.071	0.151	0.081
BLACKSTONE A-C	P	1.349	0.533	0.768	1.029	0.655	0.275	0.579	0.150	0.186	0.210
	S	0.050	0.011	0.015	0.016	0.005	0.003	0.002	N.D.	0.001	0.001
BLACKSTONE D	P	1.842	0.549	1.053	1.283	N.D.	N.D.	N.D.	0.230	0.208	N.D.
	S	0.034	0.005	0.008	0.010	0.006	0.004	0.001	0.000	0.001	0.005
TAUNTON	P	0.407	0.142	0.181	0.212	0.113	0.042	0.275	0.093	0.041	0.040

POINT SOURCES		PCB Congeners (NG/L)									
		101	151	153	138	180	170	201	195	194	209
BRISTOL	P	4.87	1.64	3.08	4.24	1.790	0.880	1.621	0.347	0.812	N.D.
BLACKSTONE VAL.	P	5.92	2.199	2.638	4.46	1.70	0.733	1.524	0.357	0.864	N.D.
	S	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
EAST GREENWICH	P	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
	S	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
EAST PROVIDENCE	P	1.454	0.427	0.704	0.903	0.332	0.127	0.435	0.128	0.130	N.D.
FIELD'S POINT	P										
	S	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
FALL RIVER	P	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
NARR. ELECTRIC	P	0.663	0.216	0.438	0.538	0.312	0.136	0.305	0.113	0.094	0.08
NEWPORT	P	6.45	2.04	3.52	4.83	2.815	0.817	2.44	0.760	3.023	0.63
WARREN	P	4.01	1.098	1.668	2.27	0.879	0.299	0.981	0.348	0.368	N.D.
JAMESTOWN	P	0.900	0.300	0.450	0.700	0.237	0.043	0.400	0.168	0.133	0.06
QUONSET POINT	P	9.29	3.068	3.79	6.04	2.79	1.15	2.35	0.58	1.01	0.16

P= Particulate S= Soluble

N.D.= Not detected

TableA-18. Concentrations of organics in rivers and point sources discharging into Narragansett Bay (May 19-22, 1986).

RIVERS		HCHs (NG/L)				Hydrocarbons (UG/L)		
		a	b	g	Total	F1-UCM	F1-RES	Tot F1
PAWTUXET A-C	P	N/A	N/A	N/A	N/A	39.5	1.73	41.2
	S	N.D.	N.D.	0.443	0.443	1.90	0.41	2.31
PAWTUXET D	P	N/A	N/A	N/A	N/A	806	15.1	821
	S	0.388	N.D.	1.483	1.871	1.88	0.18	2.06
MOSHASSUCK A-C	P	N/A	N/A	N/A	N/A	37.7	1.61	39.3
MOSHASSUCK D	P	N/A	N/A	N/A	N/A	999	31.8	1031
WOONASQUA A-C	P	N/A	N/A	N/A	N/A	25.8	1.12	26.9
WOONASQUA D	P	N/A	N/A	N/A	N/A	932	21.3	953
BLACKSTONE A-C	P	N/A	N/A	N/A	N/A	44.9	0.61	45.5
	S	0.537	0.086	1.617	2.240	0.71	0.01	0.72
BLACKSTONE D	P	N/A	N/A	N/A	N/A	308	10.3	318
	S	0.518	0.089	1.587	2.194	3.83	0.02	3.85
TAUNTON	P	N/A	N/A	N/A	N/A	20.6	1.38	22.0

POINT SOURCES		HCHs (NG/L)				Hydrocarbons (UG/L)		
		a	b	g	Total	F1-UCM	F1-RES	Tot F1
BRISTOL	P	N/A	N/A	N/A	N/A	3033	146.0	3179
BLACKSTONE VAL.	P	N/A	N/A	N/A	N/A	2109	97.3	2206
	S	N.D.	N.D.	4.92	4.92	2.78	0.06	2.84
EAST GREENWICH	P	N/A	N/A	N/A	N/A	888	26.5	915
	S	N.D.	N.D.	1.10	1.10	19.7	0.47	20.2
EAST PROVIDENCE	P	N/A	N/A	N/A	N/A	194	4.84	199
FIELD'S POINT	P	N/A	N/A	N/A	N/A	1440	52.9	1493
	S	N.D.	N.D.	13.4	13.4	36.0	2.38	38.4
FALL RIVER	P	N/A	N/A	N/A	N/A	900	23.6	924
NARR. ELECTRIC	P	N/A	N/A	N/A	N/A	59.0	0.23	59.2
NEWPORT	P	N/A	N/A	N/A	N/A	1484	133	1617
WARREN	P	N/A	N/A	N/A	N/A	342	10.4	352
JAMESTOWN	P	N/A	N/A	N/A	N/A	62.3	1.94	64
QUONSET POINT	P	N/A	N/A	N/A	N/A	800	37.2	837

N/A= Not analyzed P= Particulate S= Soluble
N.D.= Not detected

TableA-19. Concentrations of organics in rivers and point sources discharging into Narragansett Bay (May 19-22, 1986).

RIVERS		PAHs (NG/L)														
		Nap	AcL	Acn	Flu	Phe	Ane	Flr	Pyr	BaA	Chr	B(b+k)F	BaP	InP	DbA	Bpr
PAWTUXET A-C	P	N.D.	N.D.	N.D.	N.D.	5.19	N.D.	14.5	31.6	27.3	63.3	146	49.1	N.D.	N.D.	69.6
	S	N.D.	N.D.	N.D.	N.D.	12.0	N.D.	22.0	26.8	N.D.	3.09	10.40	N.D.	N.D.	N.D.	N.D.
PAWTUXET D	P	N.D.	N.D.	N.D.	N.D.	274	305	603	575	167	379	758	332	255	62.3	26.6
	S	N.D.	N.D.	N.D.	N.D.	88.5	N.D.	48.8	37.0	N.D.	61.2	191	N.D.	N.D.	N.D.	N.D.
MOSHASSUCK A-C	P	N.D.	N.D.	N.D.	N.D.	28.3	N.D.	57.8	51.2	22.3	48.1	90.8	36.3	42.7	N.D.	58.0
MOSHASSUCK D	P	N.D.	N.D.	N.D.	N.D.	644	89.2	1196	983	355	721	1232	533	429	96.5	583
WOONASQUA A-C	P	N.D.	N.D.	N.D.	N.D.	10.4	N.D.	19.2	14.8	6.33	12.9	26.7	11.3	7.70	N.D.	10.3
WOONASQUA D	P	N.D.	N.D.	N.D.	N.D.	241	19.6	431	391	162	308	453	185	156	42.0	133
BLACKSTONE A-C	P	N.D.	N.D.	N.D.	N.D.	24.7	N.D.	13.1	10.0	7.95	17.1	13.2	N.D.	N.D.	N.D.	N.D.
	S	3.45	N.D.	N.D.	10.1	17.1	N.D.	19.9	15.2	N.D.	11.2	23.0	N.D.	N.D.	N.D.	N.D.
BLACKSTONE D	P	N.D.	N.D.	N.D.	N.D.	81.6	N.D.	238	251	153	304	548	254	249	165	235
	S	N.D.	N.D.	N.D.	N.D.	139	N.D.	95.4	49.7	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
TAUNTON	P	N.D.	N.D.	N.D.	N.D.	32.5	2.12	6.04	9.63	3.23	12.5	21.6	5.26	N.D.	N.D.	N.D.

POINT SOURCES		PAHs (NG/L)														
		Nap	AcL	Acn	Flu	Phe	Ane	Flr	Pyr	BaA	Chr	B(b+k)F	BaP	InP	DbA	Bpr
BRISTOL	P	N.D.	N.D.	18.3	6.14	192	N.D.	243	366	99.0	159	278	N.D.	N.D.	N.D.	N.D.
BLACKSTONE VAL.	P	N.D.	N.D.	N.D.	N.D.	123	39.3	157	375	51.5	90.1	166	N.D.	N.D.	N.D.	N.D.
	S	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	10.1	10.1	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
EAST GREENWICH	P	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	62.3	N.D.	72.7	N.D.	N.D.	N.D.	N.D.
	S	22.4	N.D.	N.D.	N.D.	70.0	21.5	29.2	27.6	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
EAST PROVIDENCE	P	7.97	N.D.	3.27	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	50.0	81.3	N.D.	N.D.	N.D.	N.D.
FIELDS POINT	P	N.D.	N.D.	N.D.	N.D.	167	N.D.	190	269	N.D.	118	210	N.D.	N.D.	N.D.	N.D.
	S	519	N.D.	N.D.	N.D.	214	N.D.	63.3	30.0	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
FALL RIVER	P	356	N.D.	N.D.	N.D.	244	N.D.	66.9	208	N.D.	29.2	48.2	N.D.	N.D.	N.D.	N.D.
NARR. ELECTRIC	P	N.D.	N.D.	N.D.	N.D.	11.7	N.D.	21.8	21.0	6.82	23.7	56.0	10.8	N.D.	N.D.	N.D.
NEWPORT	P	N.D.	N.D.	N.D.	N.D.	253	16.0	265	215	81.5	106	207	N.D.	N.D.	N.D.	N.D.
WARREN	P	58.4	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	111	N.D.	55.2	64.2	N.D.	N.D.	N.D.	N.D.
JAMESTOWN	P	1.46	N.D.	N.D.	N.D.	19.6	N.D.	22.0	34.0	6.84	27	81.9	9.75	N.D.	N.D.	N.D.
QUONSET POINT	P	N.D.	N.D.	29.5	N.D.	260	N.D.	253	346	122	193	319	N.D.	N.D.	N.D.	N.D.

P= Particulate S= Soluble

N.D.= Not detected

Table A-20. Concentrations of organics in rivers and point sources discharging into Narragansett Bay (May 19-22, 1986).

RIVERS		BZTs (NG/L)				Phthalates (UG/L)			Sterols(UG/L)
		C10	CL	C1	DBP	BBP	DEHP	DOP	Cop
PAWTUXET A-C	P	74.5	N.D.	N.D.	N.D.	0.03	0.67	N.D.	3.30
	S	N.D.	N.D.	9440	N.D.	0.48	0.15	N.D.	0.12
PAWTUXET D	P	N.D.	N.D.	1640	N.D.	N.D.	3.04	N.D.	7.99
	S	N.D.	N.D.	2270	N.D.	0.07	N.D.	N.D.	0.10
MOSHASSUCK A-C	P	N.D.	N.D.	N.D.	N.D.	N.D.	0.60	N.D.	0.64
MOSHASSUCK D	P	N.D.	N.D.	N.D.	N.D.	N.D.	1.59	N.D.	3.29
WOONASQUA A-C	P	N.D.	N.D.	N.D.	N.D.	N.D.	0.44	N.D.	1.40
WOONASQUA D	P	N.D.	N.D.	N.D.	N.D.	0.32	1.17	N.D.	4.86
BLACKSTONE A-C	P	N.D.	N.D.	N.D.	N.D.	0.04	0.17	N.D.	0.17
	S	N.D.	N.D.	N.D.	N.D.	0.04	0.10	N.D.	0.03
BLACKSTONE D	P	N.D.	N.D.	N.D.	N.D.	0.13	1.59	N.D.	4.62
	S	N.D.	N.D.	N.D.	N.D.	0.13	0.07	0.02	0.06
TAUNTON	P	N.D.	N.D.	N.D.	N.D.	N.D.	0.28	N.D.	0.43

POINT SOURCES		BZTs (NG/L)				Phthalates (UG/L)			Sterols(UG/L)
		C10	CL	C1	DBP	BBP	DEHP	DOP	Cop
BRISTOL	P	N.D.	N.D.	N.D.	N.D.	5.83	17.4	N.D.	368
BLACKSTONE VAL.	P	N.D.	N.D.	N.D.	N.D.	2.14	13.5	N.D.	75.7
	S	N.D.	N.D.	N.D.	N.D.	0.21	0.05	0.03	0.31
EAST GREENWICH	P	N.D.	N.D.	N.D.	N.D.	N.D.	43.5	N.D.	132
	S	N.D.	N.D.	340	N.D.	1.57	1.19	0.25	0.89
EAST PROVIDENCE	P	N.D.	N.D.	N.D.	N.D.	2.34	3.62	N.D.	25.0
FIELD'S POINT	P	N.D.	N.D.	N.D.	N.D.	N.D.	7.94	N.D.	64.8
	S	N.D.	N.D.	N.D.	N.D.	3.31	0.01	0.15	5.14
FALL RIVER	P	N.D.	N.D.	N.D.	N.D.	N.D.	3.25	N.D.	13.8
NARR. ELECTRIC	P	N.D.	N.D.	N.D.	N.D.	0.11	3.33	N.D.	0.66
NEWPORT	P	N.D.	N.D.	N.D.	N.D.	5.47	24.0	N.D.	945
WARREN	P	N.D.	N.D.	N.D.	N.D.	N.D.	3.11	N.D.	20.3
JAMESTOWN	P	N.D.	N.D.	N.D.	N.D.	N.D.	0.80	N.D.	3.07
QUONSET POINT	P	N.D.	N.D.	N.D.	N.D.	N.D.	5.95	N.D.	213

P= Particulate S= Soluble

N.D.= Not detected

APPENDIX B.

Concentrations of components in Narragansett Bay water column samples.

Table B-1. Concentrations of organics in the waters of Narragansett Bay (October 21-25, 1985).

SAMPLE CODE NUMBER		PCBs (NG/L)			
		Ar 1242	Ar 1254	Ar 1260	Total
STATION 2					
B-02-0.4-0-10/85	P	N.D.	3.09	1.99	5.08
B-02-2.5-0-10/85	P	2.64	5.33	6.09	14.1
	S	1.13	1.00	N.D.	2.13
B-02-5.6-0-10/85	P	2.88	8.39	6.17	17.4
	S	N.D.	N.D.	N.D.	N.D.
B-02-12.5-0-10/85	P	0.69	1.53	1.23	3.45
STATION 4					
B-04-0.3-0-10/85	P	2.37	2.75	1.36	6.48
B-04-3.3-0-10/85	P	1.32	1.56	1.06	3.94
B-04-9.9-0-10/85	P	0.89	1.53	1.19	3.61
STATION 7					
B-07-0.5-0-10/85	P	0.97	1.32	0.89	3.18
B-07-2.9-0-10/85	P	0.88	1.37	0.94	3.19
B-07-5.0-0-10/85	P	1.17	1.40	1.06	3.63
STATION 12					
B-12-0.3-0-10/85	P	2.85	2.40	1.35	6.60
B-12-7.2-0-10/85	P	0.99	1.29	0.83	3.11
B-12-15.0-0-10/85	P	0.62	0.98	0.76	2.36
B-12-25.4-0-10/85	P	0.95	1.08	0.87	2.90

N.D.= Not detected P= Particulate S= Soluble

Table B-2. Concentrations of organics in the waters of Narragansett Bay (October 21-25, 1985).

SAMPLE CODE NUMBER		PCB Congeners (NG/L)									
		101	151	153	138	180	170	201	195	194	209
STATION 2											
B-02-0.4-0-10/85	P	0.365	0.136	0.248	0.344	0.190	0.088	0.274	0.090	0.055	0.056
B-02-2.5-0-10/85	P	0.610	0.286	0.579	0.744	0.613	0.290	0.392	0.065	0.119	0.077
	S	0.102	0.024	0.035	0.042	0.006	0.009	0.023	0.009	0.005	0.005
B-02-5.6-0-10/85	P	0.646	0.252	0.606	0.886	0.646	0.298	0.433	0.134	0.176	0.202
	S	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
B-02-12.5-0-10/85	P	0.141	0.057	0.114	0.163	0.109	0.048	0.151	0.054	0.036	0.043
STATION 4											
B-04-0.3-0-10/85	P	0.339	0.114	0.146	0.211	0.097	0.034	0.250	0.089	0.034	0.037
B-04-3.3-0-10/85	P	0.196	0.067	0.093	0.136	0.072	0.027	0.230	0.081	0.030	0.034
B-04-9.9-0-10/85	P	0.162	0.058	0.115	0.161	0.093	0.035	0.227	0.090	0.030	0.067
STATION 7											
B-07-0.5-0-10/85	P	0.162	0.057	0.085	0.102	0.046	0.017	0.212	0.080	0.028	0.032
B-07-2.9-0-10/85	P	0.163	0.058	0.087	0.110	0.066	0.018	0.217	0.082	0.029	0.046
B-07-5.0-0-10/85	P	0.166	0.062	0.097	0.118	0.075	0.022	0.253	0.102	0.034	0.046
STATION 12											
B-12-0.3-0-10/85	P	0.364	0.120	0.114	0.149	0.076	0.019	0.327	0.114	0.036	0.040
B-12-7.2-0-10/85	P	0.132	0.054	0.058	0.076	0.037	0.014	0.205	0.078	0.025	0.026
B-12-15.0-0-10/85	P	0.097	0.037	0.056	0.073	0.049	0.015	0.181	0.068	0.025	0.035
B-12-25.4-0-10/85	P	0.114	0.042	0.061	0.085	0.056	0.019	0.200	0.081	0.030	0.051

N.D.= Not detected P= Particulate S= Soluble

Table B-3. Concentrations of organics in the waters of Narragansett Bay (October 21-25, 1985).

SAMPLE CODE NUMBER		HCHs (NG/L) a	b	g	Total	Hydrocarbons (UG/L) F1-UCM	F1-RES	Tot F1
STATION 2								
B-02-0.4-0-10/85	P	N.D.	N.D.	N.D.	N.D.	10.1	0.64	10.7
B-02-2.5-0-10/85	P	N.D.	N.D.	N.D.	N.D.	8.81	2.3	11.1
	S	1.780	0.384	0.960	3.124	0.24	0.02	0.26
B-02-5.6-0-10/85	P	N.D.	N.D.	N.D.	N.D.	37.9	3.22	41.1
	S	1.100	N.D.	0.450	1.550	1.23	0.07	1.30
B-02-12.5-0-10/85	P	N.D.	N.D.	N.D.	N.D.	5.47	1.02	6.49
STATION 4								
B-04-0.3-0-10/85	P	N.D.	N.D.	N.D.	N.D.	4.42	0.74	5.16
B-04-3.3-0-10/85	P	N.D.	N.D.	N.D.	N.D.	4.23	0.30	4.52
B-04-9.9-0-10/85	P	N.D.	N.D.	N.D.	N.D.	6.57	1.15	7.72
STATION 7								
B-07-0.5-0-10/85	P	N.D.	N.D.	N.D.	N.D.	1.58	0.27	1.85
B-07-2.9-0-10/85	P	0.011	0.034	0.014	0.059	2.21	0.22	2.43
B-07-5.0-0-10/85	P	N.D.	N.D.	N.D.	N.D.	2.03	0.18	2.21
STATION 12								
B-12-0.3-0-10/85	P	N.D.	N.D.	N.D.	N.D.	1.89	0.31	2.20
B-12-7.2-0-10/85	P	N.D.	N.D.	N.D.	N.D.	1.63	0.24	1.87
B-12-15.0-0-10/85	P	N.D.	N.D.	N.D.	N.D.	1.73	0.13	1.86
B-12-25.4-0-10/85	P	N.D.	N.D.	N.D.	N.D.	1.88	0.20	2.08

N.D.= Not detected P= Particulate S= Soluble

Table B-4. Concentrations of organics in the waters of Narragansett Bay (October 21-25, 1985).

SAMPLE CODE NUMBER		PAHs (NG/L)														
		Nap	AcL	Acn	Flu	Phe	Ane	Flr	Pyr	BaA	Chr	B(b+k)F	BaP	InP	DbA	Bpr
STATION 2																
B-02-0.4-0-10/85	P	0.67	N.D.	N.D.	0.64	8.21	1.50	9.24	6.89	3.37	48.8	6.93	N.D.	3.11	N.D.	N.D.
B-02-2.5-0-10/85	P	0.86	0.29	0.61	0.62	9.66	0.85	14.6	15.4	3.05	14.5	10.6	5.79	3.37	1.58	14.7
	S	0.76	N.D.	6.25	2.05	4.82	N.D.	16.7	17.7	1.71	3.85	1.91	N.D.	N.D.	N.D.	N.D.
B-02-5.6-0-10/85	P	2.95	2.12	2.25	3.46	20.5	7.31	51.0	43.2	22.1	31.4	53.0	23.5	17.4	6.66	26.8
	S	0.09	0.47	4.23	2.28	4.45	2.51	24.3	24.9	1.85	4.26	1.27	N.D.	N.D.	N.D.	N.D.
B-02-12.5-0-10/85	P	0.54	N.D.	N.D.	0.42	2.25	0.86	4.37	4.46	2.50	5.11	6.51	3.61	3.12	2.01	6.70
STATION 4																
B-04-0.3-0-10/85	P	0.89	N.D.	N.D.	N.D.	1.32	1.05	2.71	2.25	0.69	1.61	2.21	2.14	0.96	N.D.	N.D.
B-04-3.3-0-10/85	P	0.52	N.D.	N.D.	N.D.	1.44	0.52	4.40	3.21	1.37	1.76	2.62	2.12	0.98	N.D.	N.D.
B-04-9.9-0-10/85	P	0.61	N.D.	N.D.	N.D.	2.83	0.68	7.61	5.90	2.65	4.16	7.72	4.38	3.20	1.54	7.24
STATION 7																
B-07-0.5-0-10/85	P	0.51	N.D.	0.29	0.27	0.80	0.65	2.03	0.82	0.55	1.32	1.08	N.D.	N.D.	N.D.	N.D.
B-07-2.9-0-10/85	P	0.46	N.D.	0.15	0.20	0.89	0.59	0.70	0.63	0.50	0.74	1.28	1.06	0.63	N.D.	N.D.
B-07-5.0-0-10/85	P	0.62	0.21	0.26	0.38	1.36	0.20	2.66	1.72	0.65	1.21	3.02	2.01	2.67	N.D.	N.D.
STATION 12																
B-12-0.3-0-10/85	P	0.36	N.D.	N.D.	0.15	0.81	0.56	1.38	1.35	0.57	0.97	1.01	0.92	0.50	N.D.	N.D.
B-12-7.2-0-10/85	P	0.26	N.D.	N.D.	0.12	0.65	0.19	1.35	1.71	0.27	0.50	0.77	0.88	0.52	N.D.	N.D.
B-12-15.0-0-10/85	P	0.40	0.15	0.24	0.21	1.15	0.25	3.39	3.21	1.05	1.43	2.72	1.85	1.26	N.D.	N.D.
B-12-25.4-0-10/85	P	0.40	N.D.	N.D.	N.D.	1.43	0.55	3.03	3.79	1.19	2.12	2.48	1.94	0.91	N.D.	N.D.

N.D.= Not detected P= Particulate S= Soluble

TableB-5. Concentrations of organics in the waters of Narragansett Bay (October 21-25, 1985).

SAMPLE CODE NUMBER		BZTs (NG/L)			Phthalates (UG/L)				Sterols (UG/L)	
		C10	CL	C1	DBP	BBP	DEHP	DOP	Cop	Chol
STATION 2										
B-02-0.4-0-10/85	P	N.D.	N.D.	N.D.	N.D.	0.03	0.54	N.D.	0.33	0.74
B-02-2.5-0-10/85	P	N.D.	N.D.	N.D.	N.D.	N.D.	12.6	N.D.	3.99	26.6
	S	N.D.	N.D.	N.D.	N.D.	N.D.	0.00	N.D.	N.D.	0.11
B-02-5.6-0-10/85	P	N.D.	N.D.	N.D.	N.D.	N.D.	0.70	N.D.	0.34	1.06
	S	N.D.	N.D.	N.D.	N.D.	N.D.	0.08	N.D.	N.D.	0.03
B-02-12.5-0-10/85	P	N.D.	N.D.	N.D.	N.D.	0.01	0.16	N.D.	0.06	0.27
STATION 4										
B-04-0.3-0-10/85	P	N.D.	N.D.	N.D.	N.D.	N.D.	4.72	N.D.	0.19	1.46
B-04-3.3-0-10/85	P	N.D.	N.D.	N.D.	N.D.	0.04	0.12	N.D.	0.07	0.69
B-04-9.9-0-10/85	P	N.D.	N.D.	N.D.	N.D.	N.D.	0.05	N.D.	N.D.	0.36
STATION 7										
B-07-0.5-0-10/85	P	N.D.	N.D.	N.D.	N.D.	0.03	N.D.	N.D.	N.D.	0.50
B-07-2.9-0-10/85	P	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.56
B-07-5.0-0-10/85	P	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.43
STATION 12										
B-12-0.3-0-10/85	P	N.D.	N.D.	N.D.	N.D.	0.15	0.72	N.D.	0.07	0.79
B-12-7.2-0-10/85	P	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.07	0.40
B-12-15.0-0-10/85	P	N.D.	N.D.	N.D.	N.D.	0.03	0.18	N.D.	0.03	0.29
B-12-25.4-0-10/85	P	N.D.	N.D.	N.D.	N.D.	0.02	N.D.	N.D.	0.03	0.77

N.D.= Not detected P= Particulate S= Soluble

Table B-6. Concentrations of organics in the waters of Narragansett Bay (November 18-21, 1985).

SAMPLE CODE NUMBER		SS	PCBs (NG/L)			
		(MG/L)	Ar 1242	Ar 1254	Ar 1260	Total
STATION 2						
B-02-0.4-0-11/85	P	2.84	N.D.	2.74	2.67	5.41
B-02-2.1-0-11/85	P	2.01	N.D.	2.23	1.51	3.74
B-02-4.4-0-11/85	P	2.19	N.D.	1.85	1.38	3.23
B-02-10.7-0-11/85	P	4.04	N.D.	2.65	1.59	4.24
STATION 4						
B-04-0.7-0-11/85	P	1.89	N.D.	1.90	1.32	3.22
B-04-4.7-0-11/85	P	4.58	N.D.	1.86	N.D.	1.86
B-04-11.1-0-11/85	P	33.6	N.D.	5.35	2.96	8.31
	S		N.D.	N.D.	N.D.	N.D.
STATION 7						
B-07-0.9-0-11/85	P	2.19	N.D.	N.D.	N.D.	N.D.
B-07-3.1-0-11/85	P	3.17	N.D.	1.45	1.01	2.46
B-07-5.0-0-11/85	P	2.92	N.D.	1.15	N.D.	1.15
STATION 12						
B-12-0.6-0-11/85	P	1.16	N.D.	0.93	N.D.	0.93
B-12-7.5-0-11/85	P	1.68	N.D.	N.D.	N.D.	N.D.
B-12-21.8-0-11/85	P	3.15	N.D.	0.66	N.D.	0.66

N.D.= Not detected P= Particulate S= Soluble

Table B-7. Concentrations of organics in the waters of Narragansett Bay (November 18-21, 1985).

SAMPLE CODE NUMBER		PCB Congeners (NG/L)									
		101	151	153	138	180	170	201	195	194	209
STATION 2											
B-02-0.4-0-11/85	P	0.292	0.093	0.158	0.251	0.148	0.071	0.223	0.080	0.050	0.062
B-02-2.1-0-11/85	P	0.186	0.065	0.137	0.202	0.148	0.062	0.263	0.104	0.056	0.067
B-02-4.4-0-11/85	P	0.166	0.054	0.107	0.160	0.085	0.047	0.194	0.080	0.038	0.056
B-02-10.7-0-11/85	P	0.211	0.070	0.163	0.247	0.156	0.074	0.160	0.065	[illegible]	0.098
STATION 4											
B-04-0.7-0-11/85	P	0.164	0.061	0.110	0.153	0.068	0.060	0.204	0.088	[illegible]	0.047
B-04-4.7-0-11/85	P	0.184	0.050	0.089	0.138	0.082	0.033	0.213	0.087	[illegible]	0.061
B-04-11.1-0-11/85	P	0.462	0.146	0.343	0.514	0.274	0.128	0.364	0.153	0.067	0.218
	S	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
STATION 7											
B-07-0.9-0-11/85	P	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
B-07-3.1-0-11/85	P	0.140	0.032	0.015	0.089	N.D.	0.030	0.187	0.076	0.024	0.034
B-07-5.0-0-11/85	P	0.126	0.032	0.042	0.073	N.D.	0.026	0.140	0.064	0.018	0.027
STATION 12											
B-12-0.6-0-11/85	P	0.079	0.022	0.032	0.053	0.026	0.015	0.101	0.039	0.015	0.020
B-12-7.5-0-11/85	P	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
B-12-21.8-0-11/85	P	0.064	N.D.	0.028	0.049	0.022	0.017	0.069	0.029	0.013	0.027

N.D.= Not detected P= Particulate S= Soluble

Table B-8. Concentrations of organics in the waters of Narragansett Bay (November 18-21,1985)

SAMPLE CODE NUMBER		HCHs (NG/L)				Hydrocarbons (UG/L)		
		a	b	g	Total	F1-UCM	F1-RES	Tot F1
STATION 2								
B-02-0.4-0-11/85	P	N.D.	N.D.	N.D.	N.D.	10.4	0.67	11.0
B-02-2.1-0-11/85	P	N.D.	N.D.	N.D.	N.D.	7.42	0.27	7.69
B-02-4.4-0-11/85	P	N.D.	N.D.	N.D.	N.D.	6.17	0.18	6.35
B-02-10.7-0-11/85	P	N.D.	N.D.	N.D.	N.D.	25.3	0.82	26.1
STATION 4								
B-04-0.7-0-11/85	P	N.D.	N.D.	N.D.	N.D.	10.5	0.47	11.0
B-04-4.7-0-11/85	P	N.D.	N.D.	N.D.	N.D.	6.64	0.40	7.04
B-04-11.1-0-11/85	P	N.D.	N.D.	N.D.	N.D.	27.1	1.20	28.3
	S	0.793	N.D.	0.202	0.995	0.13	0.08	0.21
STATION 7								
B-07-0.9-0-11/85	P	N.D.	N.D.	N.D.	N.D.	3.24	0.39	3.63
B-07-3.1-0-11/85	P	N.D.	N.D.	N.D.	N.D.	3.06	0.28	3.34
B-07-5.0-0-11/85	P	N.D.	N.D.	N.D.	N.D.	2.53	0.22	2.75
STATION 12								
B-12-0.6-0-11/85	P	N.D.	N.D.	N.D.	N.D.	3.10	0.23	3.33
B-12-7.5-0-11/85	P	N.D.	N.D.	N.D.	N.D.	2.39	0.20	2.59
B-12-21.8-0-11/85	P	N.D.	N.D.	N.D.	N.D.	2.93	0.38	3.31

N.D.= Not detected P= Particulate S= Soluble

Table B-9. Concentrations of organics in the waters of Narragansett Bay (November 18-21, 1985).

SAMPLE CODE NUMBER		PAHs (NG/L)														
		Nap	AcL	Acn	Flu	Phe	Ane	Flr	Pyr	BaA	Chr	B(b+k)F	BaP	InP	DbA	Bpr
STATION 2																
B-02-0.4-0-11/85	P	0.57	N.D.	N.D.	N.D.	3.25	N.D.	5.53	5.44	2.68	4.94	6.80	3.13	2.02	N.D.	4.02
B-02-2.1-0-11/85	P	N.D.	N.D.	N.D.	N.D.	2.81	0.68	6.36	5.68	2.53	4.45	8.58	5.61	2.61	1.14	4.22
B-02-4.4-0-11/85	P	N.D.	N.D.	N.D.	N.D.	2.32	0.32	6.94	5.04	2.50	3.22	5.27	2.42	2.05	1.11	6.63
B-02-10.7-0-11/85	P	0.90	N.D.	N.D.	N.D.	1.64	N.D.	5.12	4.71	4.59	6.67	16.30	4.46	3.29	0.86	N.D.
STATION 4																
B-04-0.7-0-11/85	P	0.19	N.D.	N.D.	N.D.	2.23	N.D.	4.48	3.80	1.13	2.53	5.69	2.07	2.17	N.D.	4.81
B-04-4.7-0-11/85	P	1.15	N.D.	N.D.	N.D.	4.65	N.D.	6.72	5.52	2.14	3.89	7.65	2.90	3.10	N.D.	4.67
B-04-11.1-0-11/85	P	4.73	N.D.	0.75	2.23	13.1	3.14	22.9	22.0	8.28	14.5	30.0	12.8	9.63	3.12	19.2
	S	1.62	N.D.	N.D.	0.29	0.95	N.D.	3.12	3.01	N.D.	7.71	N.D.	N.D.	N.D.	N.D.	N.D.
STATION 7																
B-07-0.9-0-11/85	P	0.59	N.D.	N.D.	N.D.	2.24	N.D.	3.36	3.93	0.80	1.36	1.61	0.93	1.22	N.D.	2.00
B-07-3.1-0-11/85	P	0.00	N.D.	N.D.	0.24	2.04	N.D.	3.81	4.59	0.78	1.60	1.87	1.12	0.75	0.45	1.84
B-07-5.0-0-11/85	P	0.48	N.D.	0.82	N.D.	1.27	0.50	2.14	3.45	0.47	0.98	1.20	1.01	0.54	N.D.	N.D.
STATION 12																
B-12-0.6-0-11/85	P	N.D.	N.D.	0.28	N.D.	1.36	N.D.	2.71	3.00	0.53	1.21	1.47	1.02	0.75	N.D.	N.D.
B-12-7.5-0-11/85	P	1.10	N.D.	1.20	1.78	3.16	N.D.	4.23	3.35	1.88	2.26	4.02	3.13	3.38	N.D.	N.D.
B-12-21.8-0-11/85	P	0.24	N.D.	0.22	0.64	1.88	0.90	3.08	3.22	1.13	2.84	3.01	2.33	1.03	N.D.	N.D.

N.D.= Not detected P= Particulate S= Soluble

Table B-10 Concentrations of organics in the waters of Narragansett Bay (November 18-21,1985).

SAMPLE CODE NUMBER		BZTs (NG/L)			Phthalates (UG/L)				Sterols (UG/L)	
		C10	CL	C1	DBP	BBP	DEHP	DOP	Cop	Chol
STATION 2										
B-02-0.4-0-11/85	P	N.D.	N.D.	N.D.	N.D.	0.14	0.30	N.D.	0.06	0.10
B-02-2.1-0-11/85	P	N.D.	N.D.	N.D.	N.D.	0.10	N.D.	N.D.	N.D.	0.30
B-02-4.4-0-11/85	P	N.D.	N.D.	30.0	N.D.	0.05	N.D.	0.02	0.06	0.23
B-02-10.7-0-11/85	P	N.D.	N.D.	N.D.	N.D.	0.04	N.D.	0.15	N.D.	0.39
STATION 4										
B-04-0.7-0-11/85	P	N.D.	N.D.	130	N.D.	0.08	1.88	0.05	0.10	0.30
B-04-4.7-0-11/85	P	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.10	N.D.	1.61
B-04-11.1-0-11/85	P	13.9	4.49	N.D.	N.D.	0.17	N.D.	0.17	N.D.	0.83
	S	N.D.	N.D.	20.0	N.D.	0.04	0.31	0.24	N.D.	0.01
STATION 7										
B-07-0.9-0-11/85	P	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.15	N.D.	0.23
B-07-3.1-0-11/85	P	N.D.	N.D.	50.0	N.D.	0.27	N.D.	0.12	N.D.	0.30
B-07-5.0-0-11/85	P	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.39
STATION 12										
B-12-0.6-0-11/85	P	N.D.	N.D.	N.D.	N.D.	0.17	N.D.	N.D.	N.D.	0.14
B-12-7.5-0-11/85	P	N.D.	N.D.	N.D.	N.D.	0.05	N.D.	N.D.	N.D.	0.14
B-12-21.8-0-11/85	P	N.D.	N.D.	N.D.	N.D.	N.D.	0.67	0.46	N.D.	1.54

N.D.= Not detected P= Particulate S= Soluble

TableB-11. Concentrations of organics in the waters of Narragansett Bay (April 7-10, 1986).

SAMPLE CODE NUMBER		SS	PCBs (NG/L)			
		(MG/L)	Ar 1242	Ar 1254	Ar 1260	Total
STATION 2						
B-02-0.1-0-4/86	P	3.96	N.D.	1.56	1.00	2.56
B-02-1.7-0-4/86	P	4.05	N.D.	3.59	N.D.	3.59
B-02-13-0-4/86	P	2.27	N.D.	1.24	0.52	1.76
STATION 4						
B-04-0.3-0-4/86	P	3.84	N.D.	3.94	N.D.	3.94
B-04-2.2-0-4/86	P	4.04	N.D.	1.05	1.06	2.11
B-04-13.6-0-4/86	P	3.42	N.D.	N.D.	N.D.	N.D.
STATION 7						
B-07-0.5-0-4/86	P	2.00	N.D.	1.40	N.D.	N.D.
B-07-4.3-0-4/86	P	1.81	N.D.	N.D.	N.D.	N.D.
B-07-6.1-0-4/86	P	2.79	N.D.	2.13	N.D.	2.13
STATION 12						
B-12-0.3-0-4/86	P	1.67	N.D.	1.81	0.58	2.39
B-12-11.3-0-4/86	P	1.89	N.D.	0.72	0.25	0.12
B-12-14.8-0-4/86	P	2.11	N.D.	0.44	N.D.	0.44

N.D.= Not detected P= Particulate

Table B-12. Concentrations of organics in the waters of Narragansett Bay (April 7-10, 1986).

SAMPLE CODE NUMBER		PCB Congeners (NG/L) 101	151	153	138	180	170	201	195	194	209
STATION 2											
B-02-0.1-0-4/86	P	0.150	0.050	0.079	0.116	0.074	0.031	0.062	0.020	0.015	0.015
B-02-1.7-0-4/86	P	0.366	0.009	0.169	0.268	0.148	0.062	0.131	0.084	0.033	0.050
B-02-13-0-4/86	P	0.212	0.041	0.079	0.146	0.085	N.D.	0.109	0.066	0.016	0.028
STATION 4											
B-04-0.3-0-4/86	P	0.471	0.292	0.130	0.231	0.111	0.046	0.137	0.073	0.025	0.033
B-04-2.2-0-4/86	P	0.298	N.D.	N.D.	0.186	0.087	0.037	0.082	0.051	0.018	0.029
B-04-13.6-0-4/86	P	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
STATION 7											
B-07-0.5-0-4/86	P	N.D.	N.D.	N.D.	N.D.	0.109	N.D.	0.286	0.091	N.D.	N.D.
B-07-4.3-0-4/86	P	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
B-07-6.1-0-4/86	P	0.210	0.067	0.086	0.100	0.064	N.D.	0.100	0.033	N.D.	0.001
STATION 12											
B-12-0.3-0-4/86	P	0.172	0.044	0.050	0.091	0.046	0.015	0.070	0.021	0.006	0.007
B-12-11.3-0-4/86	P	0.116	N.D.	N.D.	N.D.	0.037	N.D.	0.065	0.050	0.006	0.019
B-12-14.8-0-4/86	P	0.159	N.D.	N.D.	N.D.	N.D.	N.D.	0.062	0.044	N.D.	0.021

N.D. = Not detected P= Particulate

TableB-13 Concentrations of organics in the waters of Narragansett Bay (April 7-10, 1986).

SAMPLE CODE NUMBER		HCHs (NG/L)				Hydrocarbons (UG/L)		
		a	b	g	Total	F1-UCM	F1-RES	Tot F1
STATION 2								
B-02-0.1-0-4/86	P	N/A	N/A	N/A	N/A	20.2	1.40	21.6
B-02-1.7-0-4/86	P	N/A	N/A	N/A	N/A	16.3	0.94	17.2
B-02-13-0-4/86	P	N/A	N/A	N/A	N/A	5.77	0.39	6.16
STATION 4								
B-04-0.3-0-4/86	P	N/A	N/A	N/A	N/A	13.6	1.09	14.7
B-04-2.2-0-4/86	P	N/A	N/A	N/A	N/A	12.3	1.54	13.9
B-04-13.6-0-4/86	P	N/A	N/A	N/A	N/A	5.00	0.71	5.71
STATION 7								
B-07-0.5-0-4/86	P	N/A	N/A	N/A	N/A	4.28	0.42	4.70
B-07-4.3-0-4/86	P	N/A	N/A	N/A	N/A	4.55	0.40	4.95
B-07-6.1-0-4/86	P	N/A	N/A	N/A	N/A	3.90	0.37	4.27
STATION 12								
B-12-0.3-0-4/86	P	N/A	N/A	N/A	N/A	5.98	0.55	6.53
B-12-11.3-0-4/86	P	N/A	N/A	N/A	N/A	3.90	0.48	4.38
B-12-14.8-0-4/86	P	N/A	N/A	N/A	N/A			

N.D.= Not detected P= Particulate N/A= Not analyzed

Table B-14. Concentrations of organics in the waters of Narragansett Bay (April 7-10, 1986).

SAMPLE CODE NUMBER		PAHs (NG/L)														
		Nap	AcL	Acn	Flu	Phe	Ane	Flr	Pyr	BaA	Chr	B(b+k)F	BaP	InP	DbA	Bpr
STATION 2																
B-02-0.1-0-4/86	P	1.76	N.D.	0.70	N.D.	9.87	1.85	10.3	7.81	2.24	4.99	6.79	3.84	2.43	N.D.	N.D.
B-02-1.7-0-4/86	P	N.D.	N.D.	N.D.	0.67	5.45	N.D.	9.24	8.51	2.29	5.50	6.67	3.09	1.44	1.72	3.41
B-02-13-0-4/86	P	0.61	N.D.	N.D.	0.48	3.13	N.D.	4.70	4.01	0.93	2.20	3.62	1.47	1.07	0.67	1.42
STATION 4																
B-04-0.3-0-4/86	P	N.D.	N.D.	0.50	0.72	3.75	N.D.	6.70	5.24	1.31	2.85	5.82	2.16	1.34	0.39	N.D.
B-04-2.2-0-4/86	P	0.73	N.D.	0.31	N.D.	2.59	N.D.	3.04	3.51	0.80	2.05	4.20	1.58	1.05	N.D.	N.D.
B-04-13.6-0-4/86	P	0.70	N.D.	0.27	0.59	3.64	N.D.	4.83	5.81	0.64	1.56	4.1	1.18	N.D.	N.D.	N.D.
STATION 7																
B-07-0.5-0-4/86	P	N.D.	N.D.	0.54	N.D.	0.78	N.D.	1.78	1.02	N.D.	0.80	0.81	N.D.	N.D.	N.D.	N.D.
B-07-4.3-0-4/86	P	N.D.	N.D.	0.36	N.D.	1.48	N.D.	2.81	3.89	N.D.	4.13	1.28	N.D.	N.D.	N.D.	N.D.
B-07-6.1-0-4/86	P	N.D.	N.D.	0.46	0.21	1.84	N.D.	4.18	3.11	N.D.	2.88	1.78	N.D.	N.D.	N.D.	N.D.
STATION 12																
B-12-0.3-0-4/86	P	N.D.	N.D.	0.40	N.D.	1.31	N.D.	1.83	2.40	N.D.	1.50	2.28	N.D.	N.D.	N.D.	N.D.
B-12-11.3-0-4/86	P	0.64	N.D.	0.23	0.29	1.41	N.D.	2.47	3.69	N.D.	1.46	3.39	N.D.	N.D.	N.D.	N.D.
B-12-14.8-0-4/86	P	0.41	N.D.	0.24	N.D.	2.04	N.D.	3.12	5.15	N.D.	1.06	2.10	N.D.	N.D.	N.D.	N.D.

N.D.= Not detected P= Particulate

Table B-15 Concentrations of organics in the waters of Narragansett Bay (April 7-10, 1986).

SAMPLE CODE NUMBER		BZTs (NG/L)			Phthalates (UG/L)				Sterols
		C10	CL	C1	DBP	BBP	DEHP	DOP	Cop
STATION 2									
B-02-0.1-0-4/86	P	N.D.	N.D.	N.D.	N.D.	0.07	N.D.	N.D.	0.26
B-02-1.7-0-4/86	P	N.D.	N.D.	70.0	N.D.	0.07	0.04	N.D.	0.30
B-02-13-0-4/86	P	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.22
STATION 4									
B-04-0.3-0-4/86	P	N.D.	N.D.	N.D.	N.D.	0.09	0.04	N.D.	0.30
B-04-2.2-0-4/86	P	N.D.	N.D.	N.D.	N.D.	0.13	0.10	N.D.	0.22
B-04-13.6-0-4/86	P	N.D.	N.D.	N.D.	N.D.	0.02	0.02	N.D.	0.13
STATION 7									
B-07-0.5-0-4/86	P	N.D.	N.D.	260	N.D.	0.06	N.D.	N.D.	0.11
B-07-4.3-0-4/86	P	N.D.	N.D.	210	N.D.	0.07	0.02	0.02	0.03
B-07-6.1-0-4/86	P	N.D.	N.D.	160	N.D.	0.05	0.02	N.D.	0.10
STATION 12									
B-12-0.3-0-4/86	P	N.D.	N.D.	N.D.	N.D.	0.02	0.03	N.D.	0.24
B-12-11.3-0-4/86	P	N.D.	N.D.	N.D.	N.D.	0.03	0.03	N.D.	0.11
B-12-14.8-0-4/86	P	N.D.	N.D.	N.D.	N.D.	0.03	0.04	N.D.	0.12

N.D.= Not detected P= Particulate

TableB-16. Concentrations of organics in the waters of Narragansett Bay (May 19-22, 1986).

SAMPLE CODE NUMBER		SS (MG/L)	PCBs (NG/L)			
			Ar 1242	Ar 1254	Ar 1260	Total
STATION 2						
B-02-0.4-0-5/86	P	6.57	N.D.	10.40	5.45	15.85
B-02-4.4-0-5/86	P	4.40	N.D.	4.62	2.64	7.26
B-02-11.8-0-5/86	P	3.48	N.D.	4.20	N.D.	4.20
STATION 4						
B-04-0.5-0-5/86	P	5.72	N.D.	3.56	1.49	5.05
B-04-5.5-0-5/86	P	5.81	N.D.	2.73	N.D.	2.73
B-04-15.3-0-5/86	P	16.2	N.D.	5.13	2.24	7.37
STATION 7						
B-07-0.5-0-5/86	P	2.31	N.D.	0.30	N.D.	0.30
B-07-5.9-0-5/86	P	3.99	N.D.	1.69	1.01	2.70
STATION 12						
B-12-0.5-0-5/86	P	1.84	N.D.	1.63	0.72	2.35
B-12-10.4-0-5/86	P	2.54	1.37	1.80	0.77	3.94
B-12-15.1-0-5/86	P	3.66	1.06	1.98	0.96	4.00

N.D.= Not detected P= Particulate

Table<u>B-17</u>. Concentrations of organics in the waters of Narragansett Bay (May 19-22, 1986).

SAMPLE CODE NUMBER		PCB Congeners (NG/L)									
		101	151	153	138	180	170	201	195	194	209
STATION 2											
B-02-0.4-0-5/86	P	0.857	0.351	0.589	0.769	0.413	0.207	0.380	0.111	0.114	0.101
B-02-4.4-0-5/86	P	0.355	0.152	0.248	0.338	0.165	0.077	0.272	0.094	0.055	0.063
B-02-11.6-0-5/86	P	0.319	N.D.	0.238	0.298	N.D.	0.073	0.245	0.062	0.010	0.067
STATION 4											
B-04-0.5-0-5/86	P	0.341	0.118	0.176	0.229	0.095	0.046	0.120	0.039	0.026	0.032
B-04-5.5-0-5/86	P	0.232	0.088	0.151	0.196	0.072	0.030	0.177	0.059	0.025	0.039
B-04-15.3-0-5/86	P	0.444	0.171	0.276	0.373	0.162	0.07	0.245	0.087	0.047	0.096
STATION 7											
B-07-0.5-0-5/86	P	0.012	0.005	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
B-07-5.9-0-5/86	P	0.142	0.067	0.079	0.103	0.054	0.015	0.161	0.059	0.021	0.033
STATION 12											
B-12-0.5-0-5/86	P	0.152	0.061	0.059	0.073	0.023	0.004	0.132	0.046	0.012	0.017
B-12-10.4-0-5/86	P	0.183	0.071	0.065	0.080	0.018	0.005	0.139	0.047	0.012	0.020
B-12-15.1-0-5/86	P	0.178	0.079	0.081	0.102	0.041	0.010	0.189	0.070	0.019	0.032

N.D.= Not detected   **P= Particulate**

Table B-19. Concentrations of organics in the waters of Narragansett Bay (May 19-22, 1986).

SAMPLE CODE NUMBER	PAHs (NG/L)														
	Nap	AcL	Acn	Flu	Phe	Ane	Flr	Pyr	BaA	Chr	B(b+k)F	BaP	InP	DbA	Bpr
STATION 2															
B-02-0.4-0-5/86 P	N.D.	N.D.	N.D.	N.D.	9.46	N.D.	22.9	26.7	11.3	24.9	38.40	16.0	10.6	2.96	12.7
B-02-4.4-0-5/86 P	N.D.	N.D.	N.D.	N.D.	4.25	N.D.	6.55	5.38	3.77	8.73	13.50	6.10	4.13	0.00	4.22
B-02-11.8-0-5/86 P	N.D.	N.D.	N.D.	N.D.	5.56	N.D.	8.81	12.0	5.16	9.35	12.50	N.D.	N.D.	N.D.	N.D.
STATION 4															
B-04-0.5-0-5/86 P	N.D.	N.D.	N.D.	N.D.	3.08	N.D.	4.46	7.18	N.D.	12.0	13.70	N.D.	N.D.	N.D.	N.D.
B-04-5.5-0-5/86 P	N.D.	N.D.	N.D.	N.D.	3.20	N.D.	3.39	4.63	N.D.	3.44	6.82	N.D.	N.D.	N.D.	N.D.
B-04-15.3-0-5/86 P	N.D.	N.D.	N.D.	N.D.	6.15	N.D.	8.87	9.06	3.64	7.27	13.3	6.25	4.57	N.D.	5.34
STATION 7															
B-07-0.5-0-5/86 P	N.D.	N.D.	N.D.	N.D.	0.89	N.D.	2.97	1.37	N.D.	3.38	3.91	N.D.	N.D.	N.D.	N.D.
B-07-5.9-0-5/86 P	N.D.	N.D.	N.D.	N.D.	0.00	N.D.	2.83	3.02	N.D.	2.62	8.61	N.D.	N.D.	N.D.	N.D.
STATION 12															
B-12-0.5-0-5/86 P	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	2.08	1.36	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
B-12-10.4-0-5/86 P	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	1.63	1.60	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
B-12-15.1-0-5/86 P	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	1.59	2.79	N.D.	N.D.	0.29	N.D.	N.D.	N.D.	N.D.

N.D.= Not detected P= Particulate

TableB-18 Concentrations of organics in the waters of Narragansett Bay (May 19-22, 1986).

SAMPLE CODE NUMBER		HCHs (NG/L)				Hydrocarbons (UG/L)		
		a	b	g	Total	F1-UCM	F1-RES	Tot F1
STATION 2								
B-02-0.4-0-5/86	P	N/A	N/A	N/A	N/A	58.0	2.09	60.1
B-02-4.4-0-5/86	P	N/A	N/A	N/A	N/A	14.9	0.69	15.6
B-02-11.8-0-5/86	P	N/A	N/A	N/A	N/A	13.9	0.52	14.4
STATION 4								
B-04-0.5-0-5/86	P	N/A	N/A	N/A	N/A	18.9	0.78	19.7
B-04-5.5-0-5/86	P	N/A	N/A	N/A	N/A	8.34	0.24	8.58
B-04-15.3-0-5/86	P	N/A	N/A	N/A	N/A	16.7	0.66	17.4
STATION 7								
B-07-0.5-0-5/86	P	N/A	N/A	N/A	N/A	4.39	0.24	4.63
B-07-5.9-0-5/86	P	N/A	N/A	N/A	N/A	5.58	0.75	6.33
STATION 12								
B-12-0.5-0-5/86	P	N/A	N/A	N/A	N/A	3.70	0.24	3.94
B-12-10.4-0-5/86	P	N/A	N/A	N/A	N/A	4.15	0.27	4.42
B-12-15.1-0-5/86	P	N/A	N/A	N/A	N/A	3.43	0.18	3.61

N.D.= Not detected P= Particulate N/A = Not analyzed

Table B-20 Concentrations of organics in the waters of Narragansett Bay (May 19-22, 1986).

SAMPLE CODE NUMBER		BZTs (NG/L)			Phthalates (UG/L)				Sterols (UG/L)
		C10	CL	C1	DBP	BBP	DEHP	DOP	Cop
STATION 2									
B-02-0.4-0-5/86	P	N.D.	N.D.	N.D.	N.D.	0.06	0.10	N.D.	0.29
B-02-4.4-0-5/86	P	N.D.	N.D.	N.D.	N.D.	0.07	0.10	0.15	0.39
B-02-11.8-0-5/86	P	N.D.	N.D.	N.D.	N.D.	0.04	0.16	N.D.	0.26
STATION 4									
B-04-0.5-0-5/86	P	N.D.	N.D.	N.D.	N.D.	0.07	0.08	N.D.	0.66
B-04-5.5-0-5/86	P	N.D.	N.D.	N.D.	N.D.	0.02	0.02	N.D.	0.21
B-04-15.3-0-5/86	P	N.D.	N.D.	10.0	N.D.	0.03	0.03	N.D.	0.19
STATION 7									
B-07-0.5-0-5/86	P	N.D.	N.D.	N.D.	N.D.	N.D.	0.03	0.14	0.10
B-07-5.9-0-5/86	P	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	0.10
STATION 12									
B-12-0.5-0-5/86	P	N.D.	N.D.	N.D.	N.D.	0.01	0.01	N.D.	0.05
B-12-10.4-0-5/86	P	N.D.	N.D.	N.D.	N.D.	0.01	0.05	0.03	N.D.
B-12-15.1-0-5/86	P	N.D.	N.D.	N.D.	N.D.	0.01	0.01	0.02	0.07

N.D.= Not detected P= Particulate

Appendix 4

Narragansett Bay Project
Historical Dataset Summary Sheet

NBP Index Number:

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1) Title: Petroleum Hydrocarbons in Narragansett Bay. Survey of hydrocarbons in sewage effluents, sediments and clams (Mercenaria mercenaria).

2) Summary: See abstracts of published data.

3) Variables measured: Total hydrocarbons (mg/l effluent, mg/g dry sediment and ug/g wet tissue) and organic carbon concentration (mg/g dry sediment).

4) Sampling locations: Narragansett Bay (see map for station locations).

5) Frequency of sampling: Sewage treatment plants (total of 2) were sampled 1 to 3 times. Surface sediment stations (total of 8) were sampled 1 to 3 times. Clam samples were collected 1 or 2 times from 3 stations.

6) Time span of data: June 1969 to May 1971.

7) Principal Investigators:
Name: James G. Quinn and John W. Farrington
Organization: Graduate School of Oceanography
Address: University of Rhode Island
Narragansett, Rhode Island 02882
Telephone: (401) 792-6219
Funding: National Sea Grant Program (2-35190) and the Federal Water Quality Administration (5-FI-26, 426-01).

8) Citation for published data:

John W. Farrington, 1971.
Benthic lipids of Narragansett Bay - Fatty acids and hydrocarbons.
Ph.D. Dissertation, Graduate School of Oceanography, University of Rhode Island, 141 pp.

John W. Farrington and James G. Quinn, 1973.
Petroleum hydrocarbons in Narragansett Bay. I. Survey of hydrocarbons in sediments and clams (Mercenaria mercenaria).
Estuarine and Coastal Marine Science, Vol. 1, pp. 71-79.

John W. Farrington and James G. Quinn, 1973.
Petroleum hydrocarbons and fatty acids in wastewater effluents.
Journal Water Pollution Control Federation, Vol. 45, pp. 704-712.

9) Location of original raw data: Room 130, Horn Laboratory, GSO/URI.

10) Person to contact for data: James G. Quinn.

11) Are original data computerized: No.

12) Not applicable.

13) Not applicable.

14) Not applicable.

15) Data quality: See methods sections of published data.

16) Not applicable.

17) Not applicable.

18) Form filled out by: James G. Quinn.

19) Date: May 1988.

ABSTRACT

Analyses of the fatty acids in effluents from three secondary sewage treatment plants by gas chromatography of fatty acid methyl esters confirm that the predominant fatty acids in sewage effluents are 16:0, 18:0, and 18:1. The relative abundance of these fatty acids suggest animal fats and vegetable oils as the sources of the fatty acids. Concentrations of fatty acids ranged from 0.73 to 43.05 mg/liter.

Gas chromatographic analyses of hydrocarbons isolated from lipid extracts of sewage effluents by column chromatography and thin layer chromatography strongly indicate that petroleum hydrocarbons are discharged by two of the sewage treatment plants. Hydrocarbon concentrations ranged from none detected for the effluent of one treatment plant to 16.2 mg/liter for the effluent of another treatment plant. These results confirm earlier suggestions that significant amounts of petroleum hydrocarbons are discharged by sewage effluents.

TABLE II.—Hydrocarbons in Wastewater Effluents

Identification*	Hydrocarbon Concentrations (mg/l)
Field's Point plant:	
3/26/71 A-1	2.5
11:00 am A-2	2.4
B-1	8.5
B-2	8.3
5/5/71 A	4.4
1:30 pm B	16.2
11/23/71	12.7
9:20 am	
East Providence plant:	
5/5/71	1.0
1:30 pm	
West Warwick plant:	
3/26/71	None detected
12:00 noon	

* Letters indicate replicate samples, numbers indicate replicate analysis of sample.

Narragansett Bay

(sediment and clam samples)

Station	41° N Latitude min	41° N Latitude sec	71° W Longitude min	71° W Longitude sec
FP (S)	47	35	22	50
E_1 (S,C)	46	10	22	40
E_2 (S)	41	20	20	35
D (S)	37	35	22	05
C (S,C)	33	30	24	30
B (S)	32	25	24	25
A (S,C)	29	55	24	40
WR (S)	26	50	24	45

S = sediment

C = clam.

4-3

Journal

WATER POLLUTION CONTROL
FEDERATION

PETROLEUM HYDROCARBONS AND FATTY ACIDS IN WASTEWATER EFFLUENTS

John W. Farrington and James G. Quinn

APRIL 1973

Reprinted from *Estuarine and Coastal Marine Science* (1973) 1, 71–79

Petroleum Hydrocarbons in Narragansett Bay

1. Survey of Hydrocarbons in Sediments and Clams *(Mercenaria mercenaria)**

John W. Farrington and James G. Quinn

Chemistry Department, Woods Hole Oceanographic Institution
Woods Hole, Mass. 02543, U.S.A.
and
Graduate School of Oceanography, University of Rhode Island, Kingston
Rhode Island 02881, U.S.A.

Received 20 June 1972 and in revised form 14 November 1972

Analyses of hydrocarbons in surface sediments from eight stations and in clams (*M. mercenaria*) from three stations in Narranganset Bay show that both contain a very complex mixture of hydrocarbons which is not present in clams from Charlestown Pond, a relatively unpolluted coastal pond. This complex mixture of hydrocarbons is present in crude oils and fuel oils, and it is not a likely product of recent biosynthesis by marine organisms. This suggests that the sediments and clams from the areas sampled in Narranganset Bay are contaminated by petroleum hydrocarbons. Sewage effluents and small oil spills are the most probable sources of the petroleum hydrocarbons.

Introduction

The coastal zone receives much of the oil discharged to the marine environment. Accidental discharges of oil from tankers, shoreline storage areas and offshore wells; small spills associated with tanker-terminal transfers; discharge of ballast waters by tankers and other vessels; small craft exhaust discharges; and the discharge of oil via sewage effluents, storm sewers and industrial effluents all contribute to oil contamination in the coastal zone (Blumer, 1971). Several recent reviews and bibliographies describe oil pollution research and list the available literature (Moulder & Varley, 1971; Blumer, 1971; Pilpel, 1968; American Petroleum Institute, 1969, 1971).

Concurrent chemical analyses and biological field and laboratory studies have shown that petroleum hydrocarbons from an oil spill can persist in marine sediments for at least two years (Blumer & Sass, 1972) and that spilled oil has adverse effects on marine organisms (Blumer *et al.*, 1971*a*; Sanders *et al.*, 1972; Foster *et al.*, 1971; North *et al.*, 1965). Other investigators reported petroleum hydrocarbon contamination of fish and shellfish from coastal areas (Ehrhardt, 1972; Sidhu *et al.*, 1970; Connel, 1971).

We have made a quantitative survey of the distribution of hydrocarbons in surface sediments (0 to 8 cm) and clams (*Mercenaria mercenaria*) from several stations in Narragansett Bay as part of a larger study of the biogeochemistry of lipids in recent estuarine sediments and benthos (Farrington, 1971; Farrington & Quinn, 1971*a*, *b*; Farrington & Quinn, 1972*a*, *b*; Farrington *et al.*, 1972). Such a quantitative survey is of importance since it established the status of the area with regard to the presence of petroleum hydrocarbon contamination and provides a basis for the assessment of further deterioration or recovery.

Contribution no. 2880, Woods Hole Oceanographic Institution.

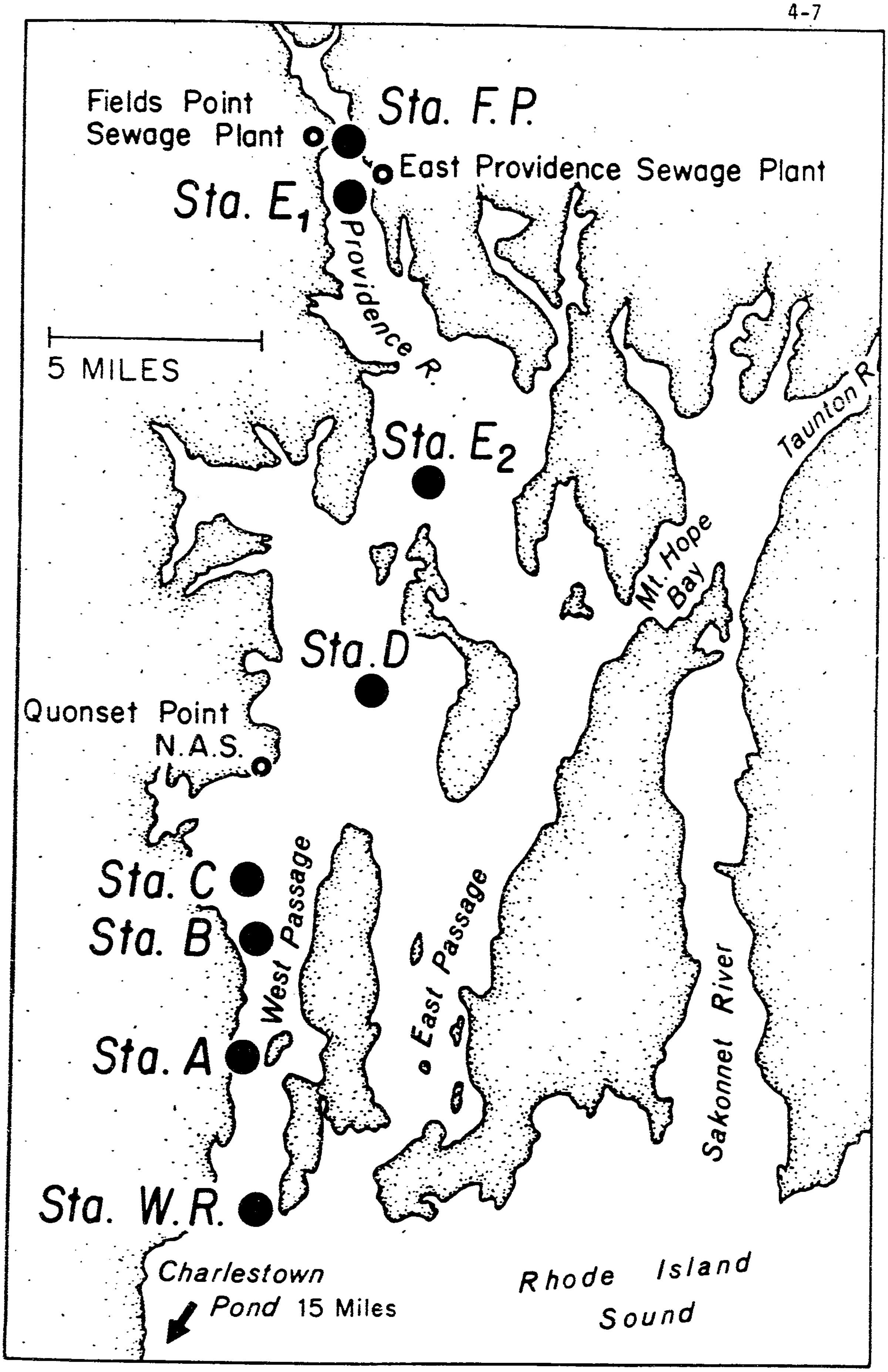
Fields Point
Sewage Plant
Sta. F.P.
East Providence Sewage Plant
Sta. E1
Providence R.
5 MILES
Sta. E2
Taunton R.
Mt. Hope Bay
Sta. D
Quonset Point
N.A.S.
Sta. C
Sta. B
West Passage
East Passage
Sakonnet River
Sta. A
Sta. W.R.
Charlestown
Pond 15 Miles
Rhode Island
Sound

TABLE 1

HYDROCARBON AND ORGANIC CARBON CONCENTRATIONS IN SEDIMENTS AND HYDROCARBON CONCENTRATIONS IN *M. mercenaria* (CLAMS)

Sediments

Station	I		II	I/II
	Hydrocarbon Conc. (mg/g dry wt.)		Organic Carbon Conc.[b] (mg/g dry wt)	(x 10^2)
	average	range		
F.P.(1)[c]	2.11	0.82-3.56	38.07	5.54
E_1 (3)	2.04	0.50-5.70	36.68	5.56
E_2 (2)	0.71	0.46-1.07	9.84	7.24
D (1)	0.40	0.35-0.44	12.62	3.13
C (2)	0.15	0.13-0.16	6.48	2.28
B (1)	0.15	---------	7.41	1.90
A (1)	0.11	0.10-0.12	6.25	1.81
W.R.(1)	0.06	0.05-0.06	5.63	1.10

M. mercenaria (Clams)

Station			Concentration of Hydrocarbons	
			(µg/g dry weight)	(mg/100 g wet weight)
E_1	12/23/70	(4)[d]	160	1.60
	5/12/71	(7)	163 (94.0)[e]	1.43 (0.82)[e]
C	12/23/70	(2)	74	1.01
	5/12/71	(2)	35 (25.5)	0.41 (0.30)
A	5/12/71	(5)	26 (10.5)	0.29 (0.12)
Charlestown Pond				
	4/71	(4)	none detectable by our method.	

Appendix 5

Narragansett Bay Project
Historical Dataset Summary Sheet

NBP Index Number:

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1) Title: Input and fate of petroleum hydrocarbons entering the Providence River and upper Narragansett Bay from sewage effluents.

2) Summary: See abstracts of published data.

3) Variables measured: Total hydrocarbons (mg/l effluent and bay water; mg/g dry sediment), total suspended solids in effluent (mg/l) and organic carbon (mg/g dry sediment).

4) Sampling locations: Providence River and upper Narragansett Bay (see map for station locations).

5) Frequency of sampling: The Fields Point treatment plant was sampled biweekly over a 1 year period. There were a total of 21 samples and each one was a 6-day composite sample. Surface water samples were collected from 4 stations (once) and sediment cores were taken at these 4 stations (once).

6) Time span of data: June 1974 to March 1976.

7) Principal Investigators:
   Name: James G. Quinn and Edward S. Van Vleet
   Organization: Graduate School of Oceanography
   Address: University of Rhode Island
   Narragansett, Rhode Island 02882
   Telephone: (401) 792-6219
   Funding: National Sea Grant Program (04-6-158-44002).

8) Citation for published data:

   Edward S. Van Vleet, 1978.
   Diagenesis of hydrocarbons, fatty acids, and isoprenoid alcohols in marine sediments.
   Ph.D. Dissertation, Graduate School of Oceanography, University of Rhode Island, 232 pp.

   Edward S. Van Vleet and James G. Quinn, 1977.
   Input and fate of petroleum hydrocarbons entering the Providence River and upper Narragansett Bay from wastewater effluents.
   Environmental Science and Technology, Vol. 11, pp. 1086-1092.

9) Location of original raw data: Room 130, Horn Laboratory, GSO/URI.

10) Person to contact for data: James G. Quinn.

11) Are original data computerized: No.

12) Not applicable.

13) Not applicable.

14) Not applicable.

15) Data quality: See methods sections of published data.

16) Not applicable.

17) Not applicable.

18) Form filled out by: James G. Quinn

19) Date: May 1988.

5-2 (cont'd)

Narragansett Bay

(water and sediment samples)

	41° N Latitude		71° W Longitude	
Station	min	sec	min	sec
1 (W,S)	48	50	23	50
2 (W,S)	47	35	22	50
3 (W,S)	45	10	22	45
4 (W,S)	43	15	21	05

W = water

S = sediment.

5-3

Reprinted from ENVIRONMENTAL SCIENCE & TECHNOLOGY, Vol. 11, Page 1086, November 1977

Input and Fate of Petroleum Hydrocarbons Entering the Providence River and Upper Narragansett Bay from Wastewater Effluents

Edward S. Van Vleet* and James G. Quinn

Graduate School of Oceanography, University of Rhode Island, Kingston, R.I. 02881

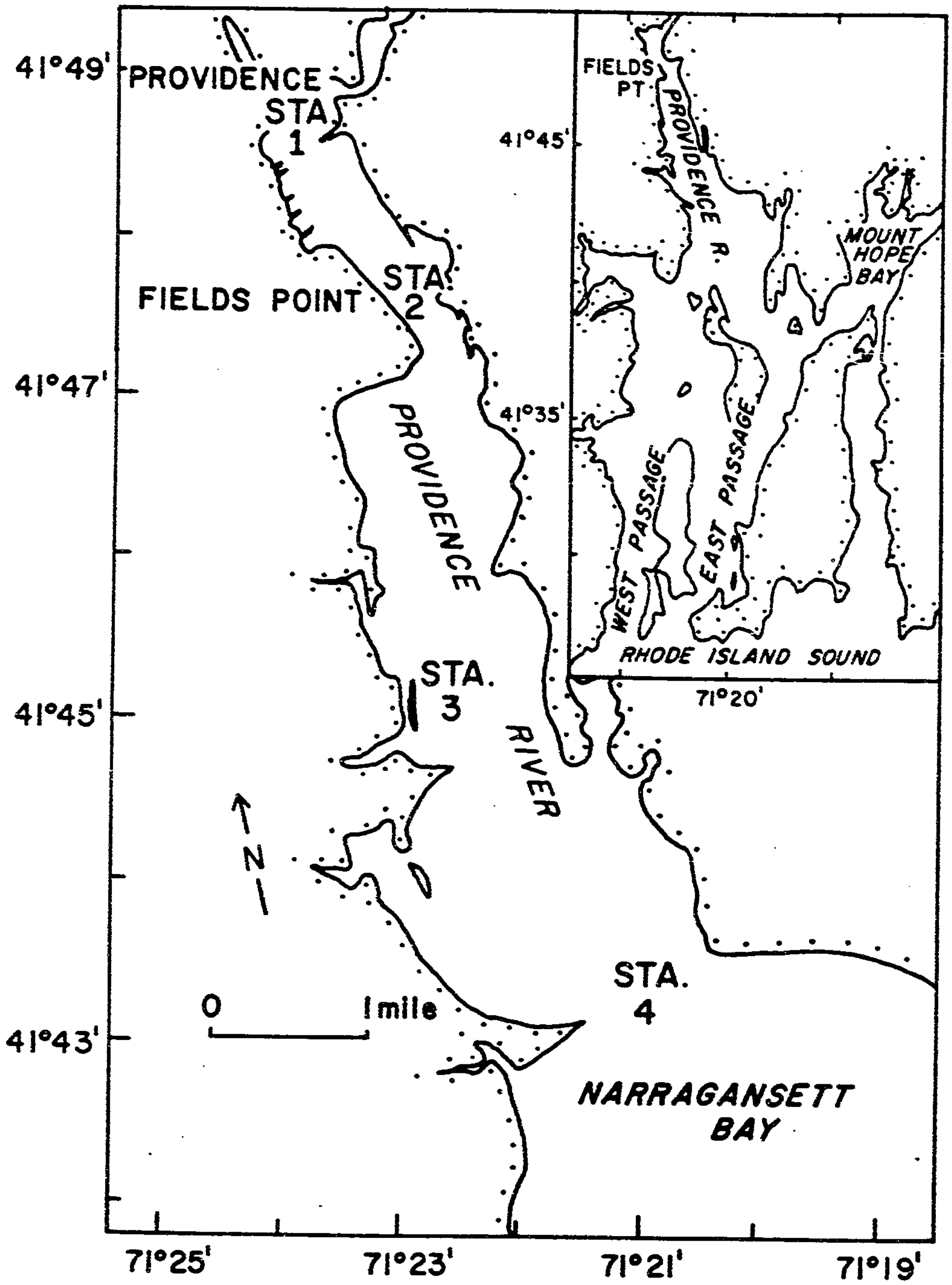
■ A one-year background survey of the petroleum hydrocarbons discharged to the Providence River by a municipal wastewater secondary treatment plant indicated that these plants may be significant contributors to oil pollution in estuarine and coastal waters. The hydrocarbons were discharged primarily in association with the suspended solids. Analysis of suspended material and sediments in the river and upper Narragansett Bay indicated that approximately half of the suspended hydrocarbons were rapidly sedimented out in the river, and the remainder were transported out of the river and throughout the bay. The petroleum products were persistent to 40 cm in some sedimentary cores with the subsequent emergence of biologically produced hydrocarbons indicating the extent to which oil pollution was present in these sediments.

By enacting the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500), the U.S. Congress established a national goal of eliminating the discharge of pollutants into navigable waters by 1985. In 1973, however, the Federal Government also established that by 1977, the minimum treatment to be applied to all public wastewater discharges would be a secondary treatment process. Standards for this process, as defined by the Environmental Protection Agency, are based on biochemical oxygen demand, suspended solids, fecal coliform bacteria, and pH (*1*). Unfortunately, the secondary treatment process is not designed to remove a significant amount of the petroleum hydrocarbons entering the treatment plant. As a result, the discharge of petroleum products in the wastewater effluent still poses an unresolved problem.

It has been estimated that domestic wastewater effluents can account for up to 5% of the total hydrocarbons entering the ocean annually (*2–5*), and the percentage entering coastal waters alone may be several times higher. Knowledge of the transport and fate of these hydrocarbons released into estuaries and coastal waters is essential in understanding their biological effects and geochemical cycles in the marine environment.

Previous studies (*6, 7*) have shown that both fulvic and humic acids can fix and retain hydrocarbons by either incorporation into a molecular sieve-type structure or hydrophobic adsorption onto the surface of these humic materials. It has also been reported (*8, 9*) that up to 50% of the organic material in sewage effluents may resemble humic substances. Consequently, these humic materials may play a major role in the transport and deposition of hydrocarbons introduced by wastewater effluents into estuaries and coastal waters.

The present study was undertaken to investigate the input of petroleum hydrocarbons to the Providence River and upper Narragansett Bay (Rhode Island) by one municipal sewage treatment plant and to determine the transport mechanisms


41°49'
PROVIDENCE
STA. 1
STA. 2
FIELDS POINT
41°47'
PROVIDENCE
RIVER
STA. 3
41°45'
N
0
1 mile
STA. 4
41°43'
NARRAGANSETT BAY
71°25'
71°23'
71°21'
71°19'
FIELDS PT
PROVIDENCE R.
41°45'
MOUNT HOPE BAY
41°35'
WEST PASSAGE
EAST PASSAGE
RHODE ISLAND SOUND
71°20'

FIELD'S POINT COMPOSITE SAMPLES DATA SUMMARY

Sample number	Dates	% of total Sol	FA	HA	Res	Total (mg/l)	$\frac{\text{Pris}}{\text{Phyt}}$	Susp. solids (mg/l)	$\frac{\text{mgHC}}{\text{mgS.S.}}$ (%)	Rain fall (in.)
1	-1974- 6/6	--	17.2	9.8	73.0	0.60	--	--	--	0.00
2	7/6 - 7/11	--	46.8	5.8	47.4	1.86	--	25.2	7.4	0.96
3	7/27-8/1	1.0	6.7	2.0	90.3	1.17	--	42.5	2.8	0.00
4	8/21-8/27	5.2	11.2	2.6	81.0	3.02	--	134.0	2.2	0.15
5	9/5 -9/11	41.7?	14.9	5.3	38.1	1.86	--	28.3	6.6	2.22
6	9/18-9/24	49.5?	11.1	4.0	35.4	3.32	--	45.0	7.4	0.62
7	10/8 -10/14	3.5	0.4	35.6	60.5	1.71	--	54.0	3.2	0.00
8	10/24-10/29	0.9	2.9	24.0	72.2	3.49	--	44.8	7.8	0.10
9	11/7 -11/13	5.4	2.1	22.5	70.0	3.24	--	72.6	4.5	0.30
10	12/9 -12/15	3.2	1.7	17.2	77.9	3.57	--	48.7	7.3	1.22
11	12/24-12/31	4.1	2.8	16.6	76.5	3.09	--	38.0	8.1	0.78
	-1975-									
12	1/8 - 1/14	11.0	15.6	5.9	67.5	1.35	1.7	49.2	2.7	3.87
13	1/30- 2/5	11.2	16.5	6.1	66.2	3.10	1.9	28.5	10.9	1.02
14	2/16- 2/22	24.9	0.9	25.1	49.1	2.61	1.8	28.8	9.1	0.15
15	3/3 - 3/9	1.8	4.5	30.3	63.4	1.81	--	47.5	3.8	0.12
16	3/23- 3/31	1.2	3.8	26.6	68.4	1.77	2.0	26.6	6.6	0.76
17	4/7 - 4/13	2.4	2.2	20.7	74.7	2.95	2.5	27.5	10.7	0.00
18	4/21- 4/27	3.7	5.7	2.3	88.3	3.50	2.1	36.5	9.6	1.22
19	5/5 - 5/11	0.3	19.6	3.4	76.7	6.58	2.4	36.8	17.9	0.08
20	6/3 - 6/9	0.3	0.0	0.4	Res = 2.3 Lip = 97.0	4.78	2.0	44.2	10.8	2.71
21	7/15- 7/21	--	--	--	Res = 0 Lip = 100	1.27	1.8	52.0	2.4	0.04
Avg.		5.3	6.4	16.1	72.2	2.80	2.0	45.5	7.1	
±S.D.		±6.3	±6.2	±11.4	±10.6	±1.31	±0.3	±23.9	±3.9	--

Table I. Distribution of hydrocarbons among the soluble, fulvic acid, humic acid, and residual fractions in the Fields Point effluent and Providence River suspended material samples ($\bar{x}$ ± s.d. as percent of total hydrocarbons).

	Soluble	Suspended			Total Hydrocarbons
		Fulvic Acid	Humic Acid	Residual	
Effluent	5 ± 6	7 ± 6	16 ± 11	72 ± 11	2.8 ± 1.3 mg/l
Suspended material:					
Station 1	NA[a]	2	1	97	21 μg/l
Station 2	NA	12	12	76	520 μg/l
Station 3	NA	2	22	76	6 μg/l
Station 4	NA	NA	NA	NA	8 μg/l
Average	-	5 ± 6	12 ± 11	83 ± 12	-

[a] NA = Not Analyzed.

Table II. Total hydrocarbon and total organic carbon data from Providence River sediment cores.

Depth	Station 1				Station 2				Station 3				Station 4			
(cm)	HC[a]	%U[b]	OC[c]	R[d]	HC	%U	OC	R	HC	%U	OC	R	HC	%U	OC	R
0-10	1.41	100	41.6	3.39	5.41	92	81.5	6.64	0.45	100	26.7	1.69	0.57	100	23.5	2.42
10-20	1.23	95	48.2	2.55	4.56	92	55.2	8.26	0.51	98	29.5	1.73	0.47	97	23.4	2.01
20-30	0.54	99	29.7	1.82	4.46	92	28.6	15.59	0.33	94	15.3	2.16	0.02	96	10.3	0.19
30-40	0.52	93	38.4	1.35	1.48	96	35.7	4.03	0.02	86	9.5	0.21	0.02	78	13.8	0.14

[a] Hydrocarbon values given in mg total hydrocarbons/g dry weight sediment.

[b] Percent of total hydrocarbons due to unresolved complex mixture.

[c] Organic carbon values given in mg total organic carbon/g dry weight sediment.

[d] R = HC/OC x 100

Appendix 6

Narragansett Bay Project
Historical Dataset Summary Sheet

NBP Index Number:

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1) Title: Hydrocarbons in urban runoff and sewage effluents discharged to the Providence River and upper Narragansett Bay.

2) Summary: See summary of published data.

3) Variables measured: Total hydrocarbons (mg/l), total and individual polycyclic aromatic hydrocarbons (ug/l) and total suspended solids (mg/l) in urban runoff and municipal effluents.

4) Sampling locations: Providence River and upper Narragansett Bay (see maps for station locations).

5) Frequency of sampling: Urban runoff samples were collected during rain events from 4 different storm drains each serving a different land use: commercial site (6 storms), residential site (3 storms), highway site (3 storms), and industrial site (7 storms). Sewage influent and effluent samples were collected from the Fields Point treatment plant during 3 rain storms and 3 analogous dry periods.

6) Time span of data: October 1979 to November 1982.

7) Principal Investigators:
   Name: Eva J. Hoffman and James G. Quinn
   Organization: Graduate School of Oceanography
   Address: University of Rhode Island
   Narragansett, Rhode Island 02882
   Telephone: (401) 792-6219.
   Funding: National Oceanic and Atmospheric Administration (NA 80RAD00047).

8) Citation for published data:

   Eva J. Hoffman and James G. Quinn, 1984.
   Hydrocarbons and other pollutants in urban runoff and combined sewer overflows.
   Final report submitted to the NOAA Oceans Assessments Division.
   Graduate School of Oceanography
   University of Rhode Island, 691 pp.

9) Location of original raw data: Room 130, Horn Laboratory, GSO/URI.

10) Person to contact for data: James G. Quinn.

11) Are original data computerized: No.

12) Not applicable.

13) Not applicable.

14) Not applicable.

15) Data quality: See methods section of published data.

16) Not applicable.

17) Not applicable.

18) Form filled out by: James G. Quinn

19) Date: May 1988.

Hydrocarbons and other pollutants in urban runoff and combined sewer overflows

National Oceanic and Atmospheric Administration
Oceans Assessments Division Grant NA80RAD00047

September 1980-April 1984

Eva J. Hoffman and James G. Quinn, principal investigators
Graduate School of Oceanography
University of Rhode Island
Narragansett, Rhode Island 02882

August, 1984

EXECUTIVE SUMMARY

This project was designed to assess the nature and relative magnitude of urban runoff as a pollutant entry pathway to the marine environment especially with reference to petroleum hydrocarbons (HC), polycyclic aromatic hydrocarbons (PAHs) and selected trace metals (TM). We sought to evaluate urban runoff levels as a function of land use so that the data could be used for all urban areas near the coast not just the Narragansett Bay area where the samples were collected.

Our specific objectives were: (1) to determine the magnitude of urban runoff entry of HC, PAHs, and TM to receiving waters as a function of land use and storm rainfall amounts; (2) to determine the origin of the HC, PAHs and TM in the urban runoff; (3) to determine the impact of urban runoff on municipal treatment systems and combined sewer overflows (CSOs); (4) to determine the effectiveness of various methods of urban runoff treatment (municipal treatment facilities and on-site retention basins); (5) to compare urban runoff with other sources of pollution to the marine environment, and (6) to demonstrate the utility of pollutant inventories for water quality management planning.

Samples were collected from four different storm drains, each serving a specific land use, during 21 separate storm events to assess the magnitude of urban runoff inputs. We monitored from 3-6 storms at each land use: residential (suburban neighborhood; commercial (shopping mall), highway

(8-lane interstate highway); and industrial (heavy industry). The samples were analyzed for HC and PAHs by glass capillary gas chromatography and for TM by atomic absorption spectrometry.

The urban runoff discharge rates for HC, PAHs and TM are given in Table 1. Inspection of these data reveal a strong dependence of urban runoff pollutant loading with land use; often differences by several orders of magnitude are involved. Concentrations were extremely variable during the history of each storm, but generally the highest concentrations of suspended solids, HC, PAHs and TM occurred during the periods of highest flow (flush conditions). Particle size and settleability experiments revealed that an average 53% of the urban runoff particulates were settleable and could be easily removed by treatment schemes involving sedimentation.

Analyses of street dust, roadside soil, roadside vegetation, roof top runoff, and atmospheric deposition revealed that these were only minor contributors (20%) of the petroleum in urban runoff. The bulk of the petroleum in urban runoff apparently comes from the "black stripe" of automotive crankcase oil drips in the center of traffic lanes. The chemical nature of the urban runoff HC is similar to that of used crankcase oil at all land uses except at the industrial location where variable contributions of a weathered #2 fuel oil were found. By virtue of the trace metal composition of used crankcase oil, 10-100% of the lead.

Table 1

Urban runoff loading factors as a function of land use.

(kg/km^2 of land use/yr)

Annual rainfall = 121 cm/yr

Pollutant	Residential (single family suburban)	Commercial (shopping mall)	Industrial (heavy)	Highway (8 lane)
Petroleum hydrocarbons	180	580	14000	7800
LMW-PAHs	0.009	0.100	2.42	1.220
HMW-PAHs	0.258	0.589	3.97	16.9
Fe	135	166	856	915
Mn	49.6	8.6	65.8	513
Cu	3.0 (8)	3.0 (22)	35.3	146
Pb	22.4 (36)	43.6 (82)	166	2250
Cd	0.18	0.69	0.85	2.48
Zn	43.5 (34)	n.d. (177)	639	7020

( ) as projected from National Urban Runoff Program data.

2-100% of the Zn, and 0.2-36% of the cadmium in urban runoff can be accounted for solely from crankcase oil drips in urban runoff.

Samples of sewage influent and effluent were collected at the Fields Point Wastewater Treatment Facility during three rainstorms and three analogous dry periods. Urban runoff enters the plant because 57% of the city is served by a combined sewer system (collecting sanitary, industrial and stormwater effluents) especially prevalent in older sections of the city of Providence. The urban runoff affects the plant in two ways: (1) it increases the loading rate of pollutants coming into the plant and (2) it interferes with treatment by hydraulically overloading the plant causing losses of activated sludge. On an annual basis, both of these wet weather effects together added 25% to the solids discharged by the plant, 19% to the hydrocarbons, 23% to the higher molecular weight PAHs and 9% to the lead. The treatment efficiencies during rainy conditions decreased relative to dry conditions for most pollutants due to loss of activated sludge occurring especially during upward surges in flow rate. Mass balance calculations suggest that most of the HC, PAHs and TM in the influent of this plant comes from industrial discharges.

Comparison of water flows and pollutant loadings during wet and dry conditions suggest that in Providence and the Blackstone Valley at least 14% and 46% respectively, of the total flow in the combined sewer systems during wet weather never reaches the plants but escapes untreated via one of the 87 combined sewer overflows in the two systems.

Treatment of urban runoff by the municipal treatment facility we studied was very ineffective. Negative treatment efficiencies due to hydraulic overloading at this plant were common during storms. On-site retention basins were found to be effective in removal of pollutants in urban runoff associated with particulate matter. Two storm event experiments were conducted at a retention basin serving the parking lot of a shopping center. The retention basin removed 26%-79% of the solids, 50% to 94% of the HC and 24% to 93% of the particulate PAHs from the stormwater before it was discharged into a nearby river.

Our urban runoff loading rates, our municipal treatment plant data, monitoring reports submitted by industries and municipalities to the states and EPA, oil spill data of the Coast Guard and Rhode Island, and our assessment of waste oil disposal practices were used to project the current input rates of HC, PAHs and selected TM to the Narragansett Bay drainage basin (see Table 2). Each pollutant had its own unique distribution among the different sources. And even for the same pollutant, each river and each segment of the Bay had a different input pattern. For the basin as a whole, urban runoff was the major source of HC, PAHs of higher molecular weight, Zn and Pb. Municipal treatment plants were the major source of Cu and PAHs of lower molecular weight, and a significant source of petroleum hydrocarbons and Zn. Waste oil dumping was a

Table 2

Pathways of pollutant entry to waters

of the Narragansett Bay basin.

Discharge	% of total input HC	PAH(LMW)	PAH(HMW)	Zn	Cu	Pb
Urban runoff	47.6	3.1	43.6	56.4	4.7	65.0
CSOs wet	2.7	-	-	-	3.9	5.4
CSOs dry	(7.2)	(0.3)	(6.9)	(-)	(52.6)	(3.8)
Municipal treatment	36.1	47.0	22.2	38.7	78.4	18.6
Direct industrial	2.7	7.9	1.9	2.8	9.1	0.2
Oil spills	2.2	18.9	3.3	-	-	-
Waste oil dumping	7.7	22.8	5.6	-	-	1.4
Atmospheric deposition	0.1	0.2	23.3	2.0	3.9	9.4
Mass (tons/yr)	1730	4.06	1.46	308	123	79.3

CSO dry percentages are the percentage of the input budget they represented before they were eliminated.

significant source of lower molecular weight PAHs, and atmospheric deposition was a significant source of higher molecular weight PAHs to Narragansett Bay.

Pollutant inventories are useful in water quality management decisions. Our study suggests that industrial users contribute most of the loading of contaminants we evaluated to the Providence municipal treatment facility. Therefore, the institution of industrial pretreatment regulations in Providence alone is calculated to reduce the Bay input budget for Cu by 43%. Since the Pb in urban runoff, atmospheric deposition and waste crankcase oil originates from leaded gasoline, our calculations indicate that the lead entry to Narragansett Bay could be reduced by at least 75% if lead is no longer used as a gasoline additive.

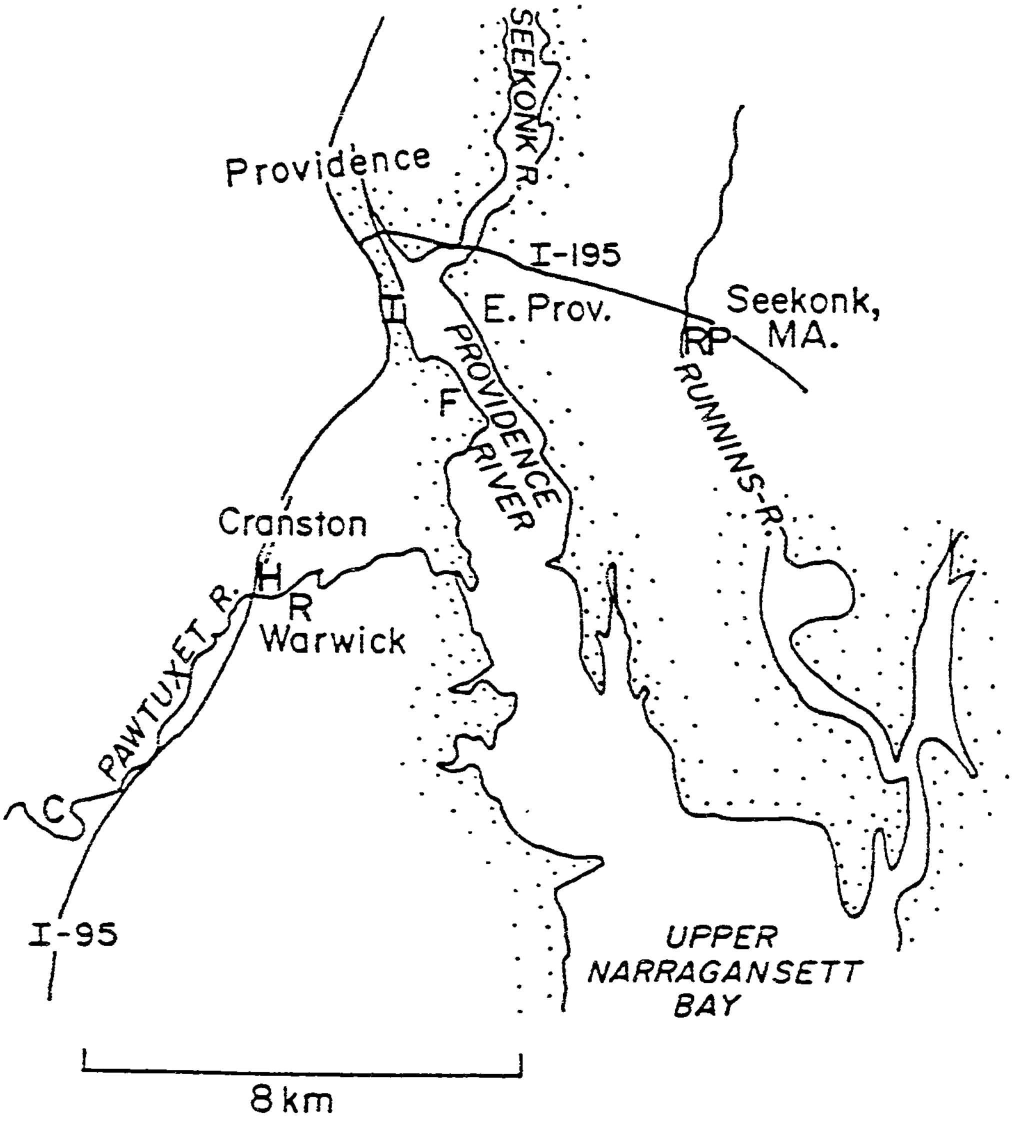

Figure 1: Urban runoff sampling locations. R = residential area drain; C = commercial area drain; I = industrial area drain; H = interstate highway drain; RP = retention pond studied; F = Fields Point Wastewater Treatment Facility.

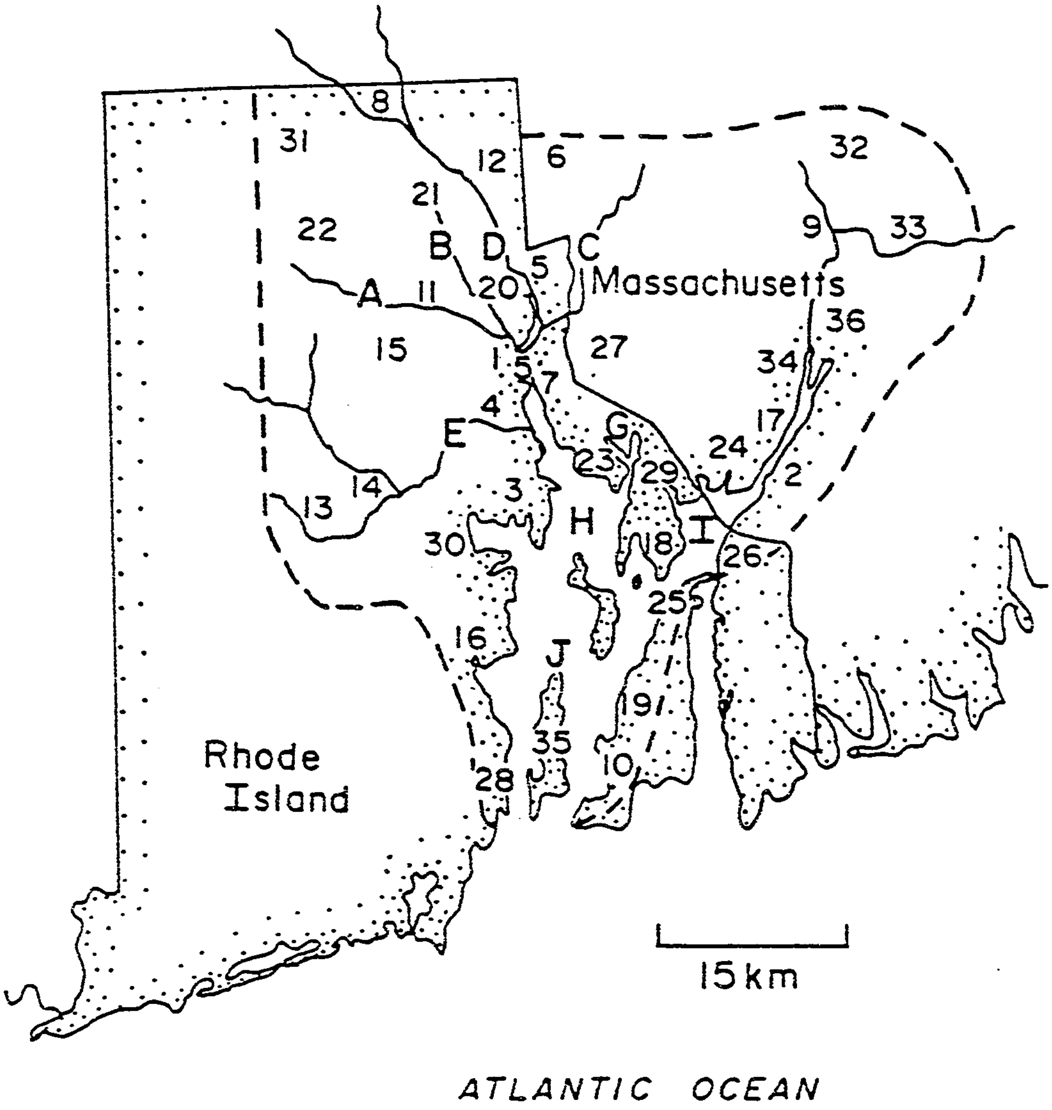

Figure 4: Narragansett Bay watershed (dashed line indicates the limits of the water pollutant inventory estimated in this study). Letters are the receiving waters considered: A = Woonasquatucket Rive B = Moshassuck River; C = Ten Mile River; D = Blackstone-Seekonk Rivers; E = Pawtuxet River; F = Providence River; G = Runnins, Barrington, Warren and Palmer Rivers: H = Upper Narragansett Bay; I = Mt. Hope Bay and Taunton River; and J = Lower Narrangansett Bay. Numbers are cities and towns in the watershed (listed in descending order): 1 = Providence; 2 = Fall River; 3 = Warwick; 4 = Cranston; 5 = Pawtucket; 6 = The Attleboros; 7 = E. Providence; 8 = Woonsocket; 9 = Taunton; 10 = Newport; 11 = N. Providence; 12 = Cumberland; 13 = Coventry; 14 = W. Warwick; 15 = Johnston; 16 = N. Kingstown; 17 = Somerset; 18 = Bristol; 19 = Middletown; 20 = Central Falls; 21 = Lincoln; 22 = Smithfield; 23 = Barrington; 24 = Swansea; 25 = Portsmouth; 26 = Tiverton; 27 = Seekonk; 28 = Narragansett; 29 = Warren; 30 = E. Greenwich; 31 = N. Smithfiel 32 = Raynham; 33 = Freetown; 34 = Dighton; 35 = Jamestown; 36 = Berkl

Appendix 7

Narragansett Bay Project
Historical Dataset Summary Sheet

NBP Index Number:

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1) Title: Suspended petroleum hydrocarbons in Narragansett Bay waters.

2) Summary: See abstracts of published data.

3) Variables measured: Total hydrocarbons (ug/l) and total suspended solids (mg/l) in bay water.

4) Sampling locations: Narragansett Bay (see map for station locations).

5) Frequency of sampling: Each station (9) was sampled 1 to 6 times. One additional station was sampled 21 times.

6) Time span of data: June 1972 to April 1974.

7) Principal Investigators:
   Name: James G. Quinn and David M. Schultz
   Organization: Graduate School of Oceanography
   Address: University of Rhode Island
   Narragansett, Rhode Island 02882
   Telephone: (401) 792-6219
   Funding: National Sea Grant Program (04-3-158-3).

8) Citation for published data:

David M. Schultz, 1974.
Source, formation and composition of suspended lipoidal material in Narragansett Bay, Rhode Island.
Ph.D. Dissertation, Graduate School of Oceanography, University of Rhode Island, 205 pp.

David M. Schultz and James G. Quinn, 1977.
Suspended material in Narragansett Bay: Fatty acid and hydrocarbon composition.
Organic Geochemistry, Vol. 1, pp. 27-36.

9) Location of original raw data: Room 130, Horn Laboratory, GSO/URI.

10) Person to contact for data: James G. Quinn.

11) Are original data computerized: No.

12) Not applicable.

13) Not applicable.

14) Not applicable.

15) Data quality: See methods sections of published data.

16) Not applicable.

17) Not applicable.

18) Form filled out by: James G. Quinn

19) Date: May 1988.

Narragansett Bay

(water samples)

Station	41° N Latitude		71° W Longitude	
	min	sec	min	sec
1A	48	50	23	50
1	47	35	22	50
2	43	15	21	05
3	39	50	22	20
3A	40	00	19	40
4	34	40	24	25
5	32	25	24	25
6	43	25	09	25
7	38	30	15	35
8	34	25	19	55

Suspended material in Narragansett Bay: fatty acid and hydrocarbon composition

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(*Received* 30 *March* 1977)

Abstract—Suspended material collected at various stations in Narragansett Bay was analyzed for fatty acids and hydrocarbons. The qualitative and quantitative distributions of these compounds indicated that the influence of sewage and other pollutants was greatest in the river areas. Based on concentrations of polyunsaturated fatty acids, the highest densities of phytoplankton were interpreted to occur at the mid and lower Bay stations, and the percentage of phytoplankton in suspended material was estimated from the concentration of heneicosahexaene. The concentrations of fatty acids and hydrocarbons in the suspended material decreased from the river stations to the mid and lower Bay stations, closely following a similar trend observed in the sediment. Possible sources of the suspended material and the influence of these sources on this material in various areas of the Bay are discussed, and attempts are made to interrelate the suspended material, resuspended sediment, phytoplankton, and sewage effluent with chemical and biochemical diagenetic changes.

INTRODUCTION

Chemical studies of organic detritus (suspended organic matter) in estuaries can aid in understanding the nutritional potential of this material for filter feeders, the establishment of estuarine food web relationships, the early biogenic and chemical diagenesis of the organic matter before reaching the sedimentary environment, and the contribution of this material to the organic matter in Recent sediments. The formation of organic detritus in estuaries is believed to result largely from the decomposition of macrophytes, including the salt marsh cord grass, *Spartina alterniflora*. This transformation was followed using fatty acids as a tracer in a recent study (Schultz and Quinn, 1973).

Organic detritus, however, is composed of more than just the decomposition products of terrestrial and marsh plants. It also consists of other materials derived from industrial and municipal effluents, river runoff, resuspended sediments, and plankton. Many species of estuarine phytoplankton have been analyzed for their fatty acid composition (Chuecas and Riley, 1969; DeMort *et al.*, 1972). The fatty acid composition of coastal plants (Maurer and Parker, 1967) and algae (Parker *et al.*, 1967) have been determined for various species. Hydrocarbons in coastal plants (Attaway *et al.*, 1970) and phytoplankton (Blumer *et al.*, 1971) have also been reported.

The fatty acids and hydrocarbons in sewage effluents from treatment plants in the Providence River section of Narragansett Bay, Rhode Island, have been reported by Farrington and Quinn (1973a), Schultz (1974), and Van Vleet and Quinn (1977). Fatty acids in plankton (mixed phyto- and zooplankton) species present in Narragansett Bay have been reported by Jeffries (1970).

Fatty acids in Recent sediment are at least partially derived from deposited suspended material, and have been reported for Narragansett Bay (Farrington and Quinn, 1971, 1973b). However, the usefulness of fatty acids as tracers in sediments and detritus may be somewhat limited because of a variety of biochemical and geochemical interactions that can substantially change the original composition of these acids.

Petroleum hydrocarbons in Recent sediment from Narragansett Bay have also been reported by Farrington and Quinn (1973c), Zafiriou (1973), and Van Vleet and Quinn (1977). There are but few reports of hydrocarbons in suspended organic matter from oceanic waters (Levy, 1971, Levy and Walton, 1973; Zsolnay, 1971), and essentially none from estuarine waters.

The purpose of this study was to extend the previous work on fatty acids as tracers of organic detritus in a salt marsh (Schultz and Quinn, 1973) to the entire estuarine ecosystem and to examine the hydrocarbons in this material, thereby acquiring background information on these lipoidal compounds in the suspended organic matter in Narragansett Bay. This study was designed to provide information on the sources of the suspended material in an estuarine environment, and to extend our present understanding of sedimentary organic matter, including sources and early diagenetic changes which occur in the suspended material before being incorporated into the sediments.

MATERIALS AND METHODS

Ten stations in Narragansett Bay, Rhode Island (Fig. 1) were selected for the collection of samples.

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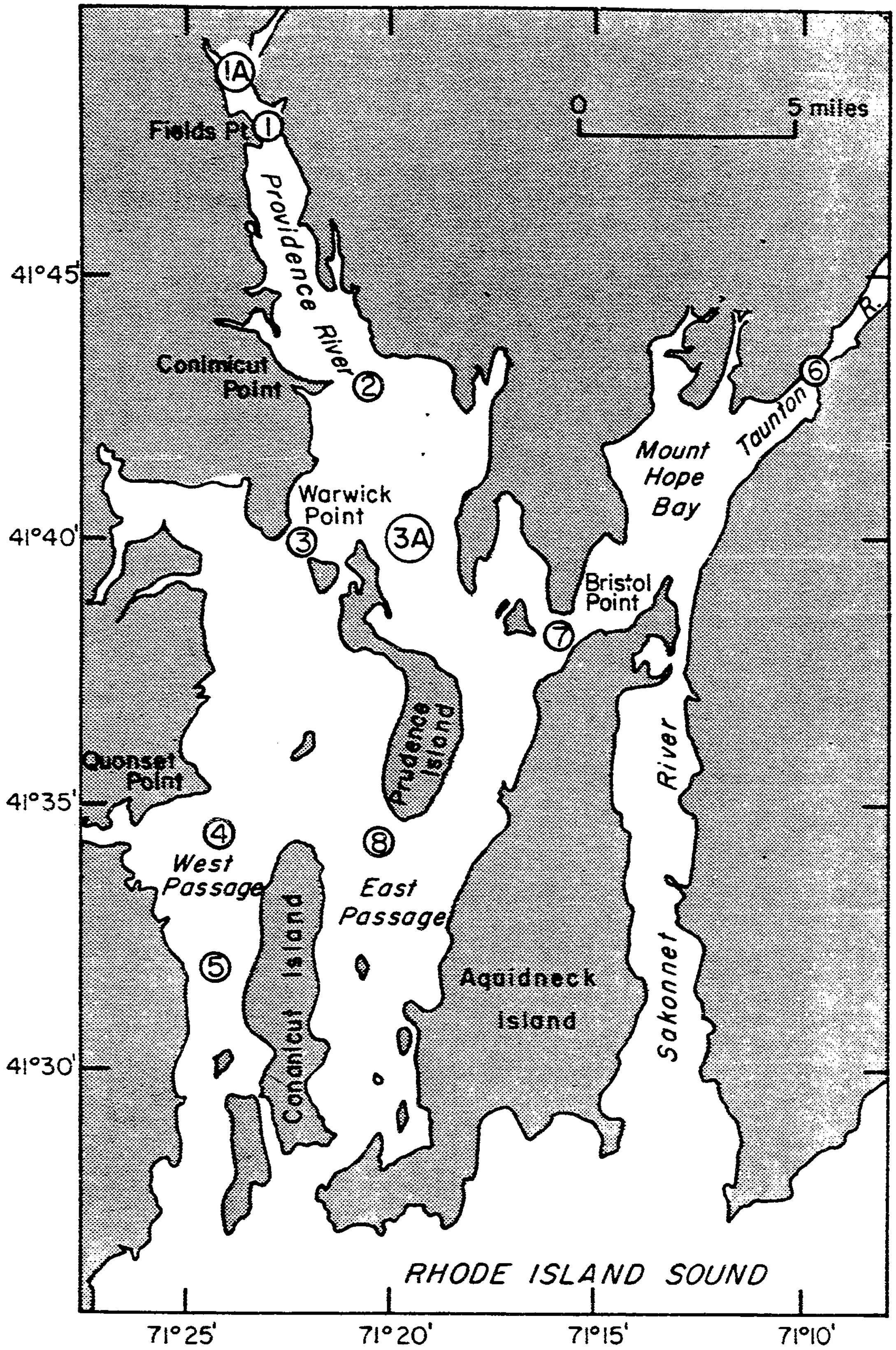
* Present address: National Center MS 973, U.S. Geological Survey, Reston, VA 22092, U.S.A.



1A
Fields Pt
1
0
5 miles
Providence River
41°45'
Conimicut Point
2
Warwick Point
3
3A
41°40'
Mount Hope Bay
Taunton
R.
6
Bristol Point
7
Prudence Island
Quonset Point
41°35'
4
West Passage
8
East Passage
River
5
Conanicut Island
Aquidneck Island
Sakonnet
41°30'
RHODE ISLAND SOUND
71°25'
71°20'
71°15'
71°10'

Table 2. Hydrocarbon concentration[a] in suspended material and water from Narragansett Bay, Rhode Island.

Station Number	Date Collected 6/30/72	8/30/72	11/8/72	1/5/73	3/9/73	5/3/73	3/1/74	Average µg/l
1A							34.8; 219	219
1	3.1; 33.7		10.9; 90.0		24.1; 154		22.1; 120	99.5 ± 51.1
2	2.4; 31.0		2.8; 5.1		22.8; 80.3		8.5; 37.4	38.5 ± 31.2
3	1.3; 22.7		0.5; 1.6		9.5; 31.4		2.1; 9.5	16.3 ± 13.3
3A							3.0; 12.9	12.9
4	0.2; 3.6	0.1; 0.5	5.9; 13.2	0.9; 2.9	6.0; 15.4	1.8; 6.7	2.2; 6.1[b]	6.9 ± 5.5
5	0.2; 2.6	0.2; 0.9	tr; tr	2.5; 5.4	3.4; 5.5	1.0; 2.4		2.8 ± 2.3
6		0.3; 1.9		4.4; 16.1		1.1; 6.0		8.0 ± 7.3
7		0.5; 1.6		4.2; 6.9		1.3; 5.0		4.5 ± 2.7
8		0.2; 0.5		3.0; 5.5		1.2; 2.6		2.9 ± 2.5

[a] Total µg hydrocarbon/mg dry weight suspended material; total µg suspended hydrocarbon/liter bay water.

[b] Sample collected on 3/4/74.

Table 3. Variation in fatty acid and hydrocarbon concentrations in suspended material from station 4, Narragansett Bay, Rhode Island.

Date Collected	Fatty acid		Hydrocarbon	
	µg/mg[a]	µg/l[b]	µg/mg	µg/l
10/15/73	6.9	39.7	0.4	2.5
11/12/73	7.5	22.3	0.6	1.8
11/26/73	15.8	58.6	0.6	2.1
12/10/73	3.4	11.8	0.5	1.8
1/02/74	8.0	14.7	3.8	6.9
1/07/74	5.9	10.9	2.4	4.5
1/21/74	7.8	13.3	3.3	5.5
2/11/74	13.7	24.6	1.6	3.0
2/20/74	9.5	23.9	1.0	2.6
2/25/74	12.7	49.8	0.9	3.5
3/04/74	33.6	93.8	2.2	6.1
3/11/74	8.2	23.1	0.9	2.4
3/25/74	23.2	57.1	1.3	3.2
4/08/74	11.4	40.0	0.7	2.5

[a] Total µg fatty acid or hydrocarbon/mg dry weight suspended material.

[b] Total µg suspended fatty acid or hydrocarbon/liter bay water.

Appendix 8

Narragansett Bay Project
Historical Dataset Summary Sheet
NBP Index Number:

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1) Title: The distribution of petroleum hydrocarbons in Narragansett Bay sediment cores.

2) Summary: See abstracts of published data.

3) Variables measured: Total hydrocarbon (ug/g dry sediment) and organic carbon (mg/g dry sediment).

4) Sampling locations: Narragansett Bay (see map for station locations).

5) Frequency of sampling: Each core station (total of 20) was sampled once.

6) Time span of data: November 1976 to September 1977.

7) Principal Investigators:
Name: James G. Quinn and Andrea C. Hurtt
Organization: Graduate School of Oceanography
Address: University of Rhode Island
Narragansett, Rhode Island 02882
Telephone: (401) 792-6219
Funding: National Sea Grant Program (04715844088).

8) Citation for published data:

Andrea C. Hurtt, 1978.
The distribution of hydrocarbons in Narragansett Bay sediment cores.
M.S. Thesis, Graduate School of Oceanography, University of Rhode Island, 69 pp.

Andrea C. Hurtt and James G. Quinn, 1979.
Distribution of hydrocarbons in Narragansett Bay sediment cores.
Environmental Science and Technology, Vol. 13, pp. 829-836.

9) Location of original raw data: Room 130, Horn Laboratory,
GSO/URI.

10) Person to contact for data: James G. Quinn.

11) Are original data computerized: No.

12) Not applicable.

13) Not applicable.

14) Not applicable.

15) Data quality: See methods sections of published data.

16) Not applicable.

17) Not applicable.

18) Form filled out by: James G. Quinn.

19) Date: May 1988.

8-2 (cont'd)

Narragansett Bay

(sediment samples)

	41° N Latitude		71° W Longitude	
Station	min	sec	min	sec
5	41	20	20	35
6	39	50	22	30
7	37	35	22	05
8	34	00	24	00
9	32	25	24	25
10	31	10	24	00
11	27	40	25	00
12	28	50	21	00
13	30	50	21	00
14	33	20	20	00
15	34	30	19	30
16	36	20	17	30
17	37	00	17	30
18	38	00	17	50
19	38	20	18	00
20	40	00	19	40
GB	40	20	24	30
L	34	20	26	15
S	33	40	23	00
W	28	40	23	15

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Distribution of Hydrocarbons in Narragansett Bay Sediment Cores

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■ Twenty cores were analyzed to provide data on the distribution of sedimentary hydrocarbons from various areas of Narragansett Bay. There was a decrease in surface (0–5 cm) sediment hydrocarbons from the Providence River to the mouth of the bay and the concentrations also decreased with depth in the cores, generally levelling off at 20–25 cm. This depth is probably related to increased petroleum utilization at the end of the 19th century. Several areas of the bay showed increasing hydrocarbons with depth, but the exact cause of this phenomenon could not be determined. The results of this study indicate that the major source of anthropogenic hydrocarbons in bay sediments is the Providence River. These compounds are introduced into the bay via tidal transport of suspended material from the river and undergo gradual sedimentation throughout the estuary.

The recent rash of oil tanker disasters off the New England coast and elsewhere has reemphasized the problem of oil pollution in the marine environment. Although accidents such as the Argo Merchant are big news, there are other sources of oil pollution that contribute as much or more oil to the estuarine and coastal zone. A 1975 NAS Report (*1*) estimated that only about 3% of the petroleum hydrocarbons introduced into the oceans annually is from tanker accidents, while 26% is from river runoff, and 10% each is from atmospheric fallout and natural seeps. The remaining inputs include urban runoff (5%), municipal wastes (5%), industrial wastes (5%), transportation (32%), coastal refineries (3%), and offshore production (1%).

It has been only during the past several years that published reports on petroleum pollution in Narragansett Bay have been available. The samples analyzed included sewage effluent, water, clams, and sediments, but the extent and nature of these samples have varied. For example, in most cases, only the surface sediments (approximately 0–10 cm) have been analyzed for hydrocarbons. Sampling areas have been concentrated in the Providence River and West Passage (*2–5*), Rhode Island Sound (*6*), and Quonset Point (*7*). One of the major problem areas is the sewage treatment plants, especially the Fields Point Plant, which contributes approximately 46% of the total sewage discharge entering Narragansett Bay, and about 71% of that enters the Bay from the Providence River (*5, 8*). With an average hydrocarbon concentration of 2.8 mg/L, this plant discharges approximately 226 metric tons of hydrocarbons into the Providence River each year (*5*). Other areas of concern are Quonset-Davisville (*7*), sites previously occupied by the Navy (e.g., Prudence Island and Melville), concentrated population locations where runoff can have higher than normal petroleum levels (e.g., Providence), and sites where previous oil spills have occurred (e.g., Popasquash Point).

The present study involves a detailed investigation of the distribution of biogenic and anthropogenic hydrocarbons in sediment cores from various depositional environments of Narragansett Bay. The sampling of the Bay is much more extensive, both in number of sites and in the depth of the cores, than previously attempted.

Experimental

Sampling and Extraction. Sediment cores from 20 stations in Narragansett Bay (Figure 1) were taken during

THE DISTRIBUTION OF HYDROCARBONS IN NARRAGANSETT BAY SEDIMENT CORES

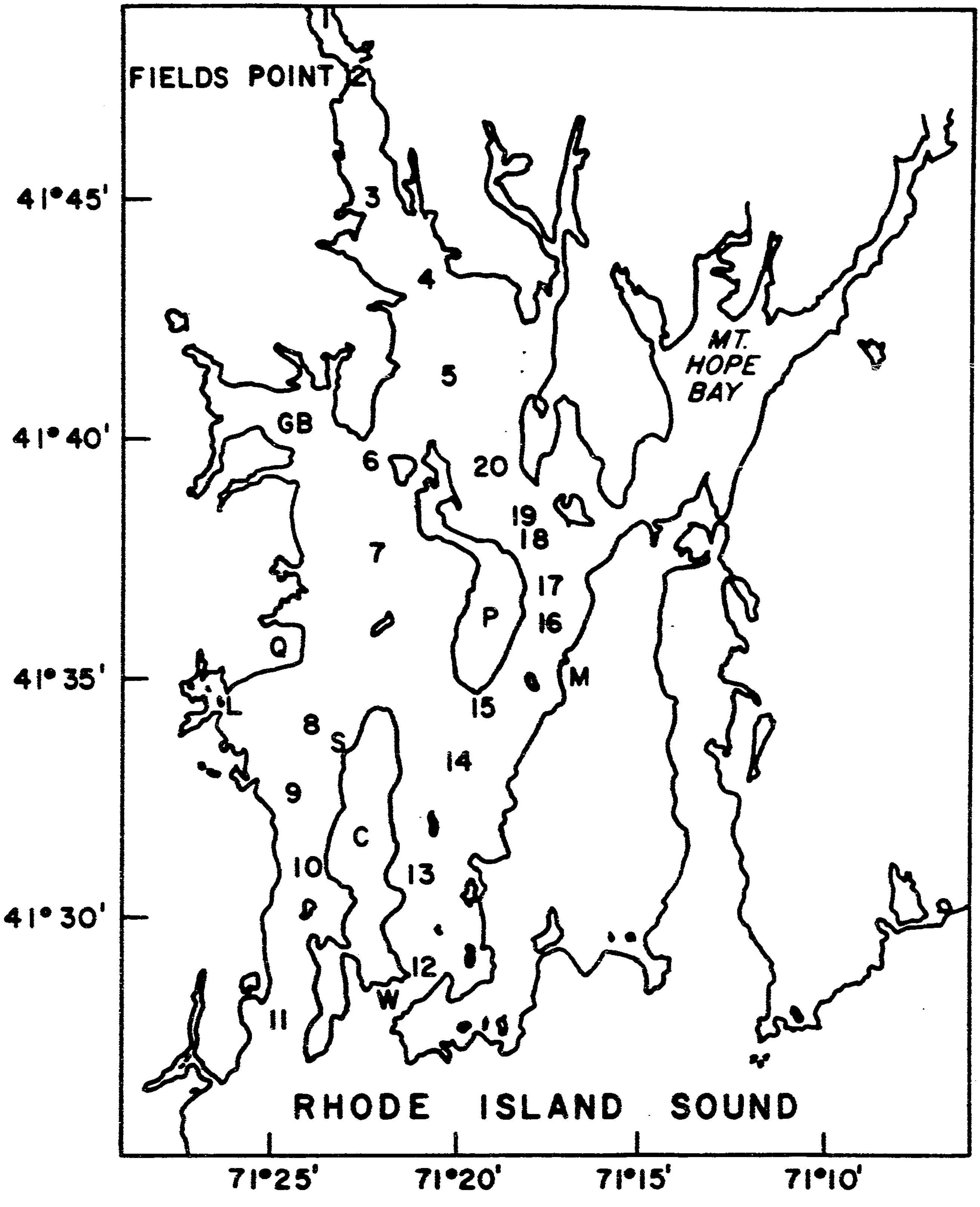
BY

ANDREA CHAPIN HURTT

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE
IN
OCEANOGRAPHY

UNIVERSITY OF RHODE ISLAND

1978


FIELDS POINT
1
2
3
4
5
6
7
8
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10
11
12
13
14
15
16
17
18
19
20
GB
Q
L
S
C
W
P
M
MT. HOPE BAY
41°45'
41°40'
41°35'
41°30'
71°25'
71°20'
71°15'
71°10'
RHODE ISLAND SOUND

Sample depth (cm)	n-C_{20} IS (μg)	g (dry wt.)	Moist (%)	Unres. (%)	Res. (%)	Total HC (μg/g dry wt.)	Biogenic HC 344 (μg/g dry wt.)	Biogenic HC 348 (μg/g dry wt.)	Org. C (mg/g dry wt.)
5-A (0-5)	100	43.93	44.9	95.7	4.3	509	.969		21.53
5-B (5-10)	100	56.27	39.22	94.3	5.7	249	.620		23.20
5-C (10-15)	100	47.82	42.81	93.3	6.7	93.0	.496		13.61
5-D (15-20)	80	50.09	44.72	83.5	16.5	17.3	.303		15.95
5-E (20-25)	20	40.95	42.87	80.4	19.6	7.29	.200		16.34
5-F (25-30)	20	48.22	39.93	66.8	33.2	7.67	.146		16.15
6-A (0-5)	500	47.03	53.1	95.5	4.5	359	1.18		27.96
6-B (5-10)	400	52.23	48.1	95.6	4.4	303	.847		20.50
6-C (10-15)	350	51.38	40.9	94.1	5.9	127	.824		15.43
6-D (15-20)	80	54.60	41	89.9	10.1	40.1	.267		15.00
6-E (20-25)	40	56.65	35.2	82.7	17.3	30.5	.382		17.30
6-F (25-30)	20	57.84	34.7	71.0	29.0	6.80	.088		10.52
6-G (30-35)	20	58.74	38.4	58.5	41.5	4.0	.05		10.51
6-H (35-40)	20	61.80	42	57.0	43.0	5.3	.14		13.82
6-I (40-45)	20	62.87	44.3	58.2	41.8	5.0	.09		12.64
6-J (45-50)	20	32.72	37.5	60.4	39.6	5.36	.15		8.41

Sample depth (cm)	n-C_{20} IS (µg)	g (dry wt.)	Moist (%)	Unres. (%)	Res. (%)	Total HC (µg/g dry wt.)	Biogenic HC 344 (µg/g dry wt.)	Biogenic HC 348 (µg/g dry wt.)	Org. C (mg/g dry wt.)
7-A (0-5)	200	31.30	45.4	95.6	4.4	356	1.99		27.91
7-B (5-10)	100	32.78	34.5	95.2	4.8	193	.99		19.60
7-C (10-15)	50	37.21	19.8	90.2	9.8	12.3	.17		9.67
7-D (15-20)	20	31.33	16.2	83.8	16.2	6.3	.11		6.75
7-E (20-25)	20	30.18	17.6	90.6	9.4	11.7	.12		7.66
7-F (25-30)	20	32.73	20.1	92.3	7.7	8.8	.09		6.83
8-A (0-2.5)	100	40.58	46.29	95.2	4.8	246	1.74		21.00
8-B (2.5-5.0)	100	41.52	43.87	96.2	3.8	255	1.69		
8-C (5-10)	100	45.60	40.12	95.8	4.2	193	1.07		16.02
8-D (10-15)	100	55.1	30.20	91.62	8.38	60.3	.508		12.79
8-E (15-20)	50	62.9	30.90	89.98	10.02	16.5	.230		12.43
8-F (20-25)	10	60.7	31.70	90.63	9.37	15.1	.168		10.57
8-G (25-30)	20	43.03	35.00	80.6	19.4	4.31	.138		9.40

Sample depth (cm)	$n\text{-}C_{20}$ IS (μg)	g (dry wt.)	Moist (%)	Unres. (%)	Res. (%)	Total HC (μg/g dry wt.)	Biogenic HC 344 (μg/g dry wt.)	Biogenic HC 348 (μg/g dry wt.)	Org. C (mg/g dry wt.)
9-A (0-5)	150	32.85	17.8	89.7	10.3	29.2	.21		2.67
9-B (5-10)	150	32.99	18.9	93.4	6.6	34.6	.23		
9-C (10-15)	150	34.83	20.0	93.8	6.2	43.6	.22		
9-D (15-20)	20	37.06	17.1	92.7	7.3	21.3	.15		
9-E (20-25)	20	43.79	20.3	93.4	6.6	20.8	.13		
10-A (0-5)	100	29.02	25.3	92.5	7.5	45.1	.60	.10	5.94
10-B (5-10)	100	29.34	31.8	93.5	6.5	80.4	.97	.11	
10-C (10-15)	100	32.76	21.0	92.5	7.5	51.0	.36	.09	
10-D (15-20)	20	37.02	21.0	88.6	11.4	9.1	.16	.01	
10-E (20-25)	20	47.58	21.1	86.7	13.3	8.9	.16	.01	
10-F (25-30)	20	39.29	17.9	86.6	13.4	8.4	.15	.004	

Sample depth (cm)	n-C_{20} IS (μg)	g (dry wt.)	Moist (%)	Unres. (%)	Res. (%)	Total HC (μg/g dry wt.)	Biogenic HC 344 (μg/g dry wt.)	Biogenic HC 348 (μg/g dry wt.)	Org. C (mg/g dry wt.)
11-A (0-5)	50	30.78	36.4	90.8	9.2	72.1	1.93	.25	7.13
11-B (5-10)	50	32.54	35.6	92.4	7.6	74.8	1.16	.11	9.20
11-C (10-15)	50	33.75	32.8	91.3	8.7	40.2	.43	.05	7.54
11-D (15-20)	20	29.29	29.6	84.4	15.5	12.0	.28	.05	9.64
11-E (20-25)	20	31.79	26.9	81.5	18.5	7.3	.26	.01	6.04
11-F (25-30)	20	35.79	21.4	80.7	19.3	4.0	.13	.008	7.15
12-A (0-5)	50	31.16	28.9	83.2	16.8	34.6	.74	.29	9.89
12-B (5-10)	50	33.20	25.3	83.6	16.4	37.8	.87	.30	
12-C (10-15)	20	30.04	20.9	72.9	27.1	42.1	.50	.17	
12-D (15-20)	10	33.18	22.9	72.7	27.3	28.0	.20	.03	

Sample depth (cm)	n-C_{20} IS (μg)	g (dry wt.)	Moist (%)	Unres. (%)	Res. (%)	Total HC (μg/g dry wt.)	Biogenic HC 344 (μg/g dry wt.)	Biogenic HC 348 (μg/g dry wt.)	Org. C (mg/g dry wt.)
13-A (0-5)	100	31.65	24.8	88.5	11.5	68.8	1.16	.43	9.80
13-B (5-10)	100	33.71	26.5	91.2	8.8	78.3	1.15	.40	
13-C (10-15)	100	40.27	20.3	92.6	7.4	47.3	.62	.15	
13-D (15-20)	50	30.52	22.4	92.9	7.1	34.9	.31	.05	
13-E (20-25)	20	38.19	22.5	90.8	9.2	11.6	.11	.03	
13-F (25-30)	20	32.70	24.2	85.1	14.9	8.4	.16	.03	
14-A (0-5)	100	32.74	56.0	93.7	6.3	283	2.90	.65	18.60
14-B (5-10)	100	35.72	51.8	93.4	6.6	361	3.30	1.17	
14-C (10-15)	100	32.43	49.7	94.6	5.4	426	1.85	.43	
14-D (15-20)	150	29.97	47.8	93.3	6.7	395	1.54	.21	
14-E (20-25)	100	30.46	48.0	93.3	6.7	263	1.58	.20	
14-F (25-30)	100	30.60	46.9	93.7	6.3	203	1.08	.31	

Sample depth (cm)	$n-C_{20}$ IS (μg)	g (dry wt.)	Moist (%)	Unres. (%)	Res. (%)	Total HC (μg/g dry wt.)	Biogenic HC 344 (μg/g dry wt.)	Biogenic HC 348 (μg/g dry wt.)	Org. C (mg/g dry wt.)
15-A (0-5)	500	53.85	19.5	95.8	4.2	112	.79		10.45
15-B (5-10)	400	52.80	14.9	95.9	4.1	70.9	.24		
15-C (10-15)	300	54.27	8.9	92.4	7.6	15.7	.10		
15-D (15-20)	200	74.88	16.8	88.9	11.1	5.28	.04		
15-E (20-23)	200	74.64	21.8	81.8	18.2	5.64	.12		
16-A (0-5)	200	31.59	39.9	94.3	5.7	333	2.00	.76	14.96
16-B (5-10)	200	31.57	34.7	92.3	7.7	183	.63	.43	
16-C (10-15)	250	31.80	35.5	93.5	6.5	72.3	.32		
16-D (15-20)	114*	32.70	35.8	91.7	8.3	58.8	.41		
16-E (20-25)	114*	32.38	30.1	94.3	5.7	50.6	.28		
16-F (25-30)	400	30.75	27.2	93.6	6.4	54.8	.35		

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*$n-C_{22}$ in place of $n-C_{20}$.

Sample depth (cm)	n-C_{20} IS (µg)	g (dry wt.)	Moist (%)	Unres. (%)	Res. (%)	Total HC (µg/g dry wt,)	Biogenic HC 344 (µg/g dry wt.)	348	Org. C (mg/g dry wt.)
17-A (0-5)	200	34.06	48.1	94.8	5.2	373	1.06	.78	19.04
17-B (5-10)	200	32.21	47.1	93.5	6.5	325	1.15	1.15	16.38
17-C (10-15)	300	31.65	38.1	93.0	7.0	445	.80	.26	21.95
17-D (15-20)	400	32.81	36.9	95.4	4.6	1650			29.69
17-E (20-25)	400	30.42	40.1	95.9	4.1	1108			16.00
17-F (25-30)	114*	32.11	35.8	92.8	7.2	117	.21		14.31
18-A (0-5)	200	32.17	54.2	94.2	5.8	361	3.45	1.05	20.54
18-B (5-10)	200	31.20	57.7	94.4	5.6	485	4.41	2.07	
18-C (10-15)	150	29.74	56.4	94.4	5.6	445	3.9	.97	
18-D (15-20)	200	31.70	55.6	94.7	5.3	536	5.6	1.03	
18-E (20-25)	200	31.18	58.9	93.4	6.6	711	5.2	1.46	
18-F (25-30)	150	30.44	54.1	94.4	5.6	450	2.31	.83	

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*n-C_{22} in place of n-C_{20}.

Sample depth (cm)	n-C_{20} IS (μg)	g (dry wt.)	Moist (%)	Unres. (%)	Res. (%)	Total HC (μg/g dry wt.)	Biogenic HC 344 (μg/g dry wt.)	Biogenic HC 348 (μg/g dry wt.)	Org. C (mg/g dry wt.)
19-A (0-5)	500	27.19	50.9	95.3	4.7	361	2.70		20.71
19-B (5-10)	200	31.50	51.9	95.9	4.1	630	1.65		
19-C (10-15)	150	31.51	50.5	95.1	4.9	577	1.89		
19-D (15-20)	250	31.78	50.2	95.3	4.7	428	1.32		
19-E (20-25)	300	35.15	48.1	94.6	5.4	557	1.45		
19-F (25-30)	300	37.47	43.0	86.9	13.1	159	.59		
20-A (0-5)	200	51.21	45.59	96.7	3.3	505	1.30	.09	29.25
20-B (5-10)	200	45.24	43.61	97.4	2.6	357	1.39	.13	
20-C (10-15)	200	55.77	43.03	96.7	3.3	310	.588	.12	
20-D (15-20)	80	67.70	43.62	96.5	3.5	137	.54	.07	
20-E (20-25)	40	66.05	43.65	93.8	6.2	129	.44	.07	
20-F (25-30)	20	70.54	42.76	86.8	13.2	18.2	.14	.01	

Sample depth (cm)	$n\text{-}C_{20}$ IS (μg)	g (dry wt.)	Moist (%)	Unres. (%)	Res. (%)	Total HC (μg/g dry wt.)	Biogenic HC 344 (μg/g dry wt.)	Biogenic HC 348 (μg/g dry wt.)	Org. C (mg/g dry wt.)
GB-A(0-5)	250	25.49	63.9	95.4	4.6	454	1.21	.30	26.45
GB-B(5-10)	150	25.75	59.6	95.7	4.3	464	1.54	.26	26.15
GB-C(10-15)	100	26.27	61.6	95.2	4.8	374	1.49	.35	24.14
GB-D(15-20)	100	29.50	58.1	93.6	6.4	405	.31	.58	23.88
GB-E(20-25)	50	30.61	54.7	94.1	5.9	385	.13	.28	21.28
GB-F(25-30)	100	23.82	53.5	93.5	6.5	321	.10	.35	17.50
L-A(0-5)	114*	30.92	25.4	90.7	9.3	63.2	.38		11.74
L-B(5-10)	114*	29.48	37.8	86.2	13.8	40.5	.15		
L-C(10-15)	114*	28.60	46.8	57.9	42.1	10.7			
L-D(15-20)	114*	31.98	40.9	58.8	41.2	8.32			
L-E(20-27)	114*	31.07	35.7	62.7	37.3	3.89			

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*$n\text{-}C_{22}$ in place of $n\text{-}C_{20}$.

Sample depth (cm)	$n\text{-}C_{20}$ IS (μg)	g (dry wt.)	Moist (%)	Unres. (%)	Res. (%)	Total HC (μg/g dry wt.)	Biogenic HC 344 (μg/g dry wt.)	Biogenic HC 348 (μg/g dry wt.)	Org. C (mg/g dry wt.)
S-A(0-2.5)	300	30.36	29.0	94.4	5.6	71.3	.55		8.64
S-B(2.5-5.0)	300	31.64	35.3	93.8	6.2	130	1.18		
S-C(5-10)	60	33.89	28.1	92.7	7.3	53.7	.43		
S-D(10-15)	60	33.83	28.0	91.9	8.1	34.7	.62		
S-E(15-20)	20	33.77	29.8	85.5	14.5	11.9	.22		
S-F(20-25)	20	30.65	31.9	82.6	17.4	15.7	.25		
S-G(25-30)	20	31.11	29.7	69.7	30.3	3.02	.12		
W-A(0-5)	60	33.01	36.2	91.4	8.6	40.5	.78	.18	5.40
W-B(5-10)	40	33.85	33.0	91.9	8.1	61.0	1.03	.26	
W-C(10-15)	40	39.61	27.2	91.7	8.3	52.0	1.57	.27	
W-D(15-20)	40	36.06	30.2	90.1	9.9	39.4	.82	.23	
W-E(20-25)	40	33.85	26.5	91.0	9.0	48.9	.61	.16	
W-F(25-30)	40	32.17	29.1	86.5	13.5	35.0	.37	.12	

Appendix 9

Narragansett Bay Project
Historical Dataset Summary Sheet

NBP Index Number:

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1) Title: Petroleum hydrocarbons in Rhode Island Sound (sediments and *Arctic islandica*).

2) Summary: See abstracts of published data.

3) Variables measured: Total hydrocarbon (ug/g dry sediment and ug/g wet tissue) and organic carbon (mg/g dry sediment).

4) Sampling locations: Narragansett Bay and Rhode Island Sound (see map for station locations).

5) Frequency of sampling: Surface sediment stations (total of 21) were sampled once and core stations (total of 2) were sampled once. Clam samples were collected once from 19 stations.

6) Time span of data: March 1975 to July 1975.

7) Principal Investigators:
   Name: James G. Quinn and Paul D. Boehm
   Organization: Graduate School of Oceanography
   Address: University of Rhode Island
   Narragansett, Rhode Island 02882
   Telephone: (401) 792-6219
   Funding: U.S. Environmental Protection Agency (R 803415-02) and the American Association of Petroleum Geologists.

8) Citation for published data:

Paul D. Boehm, 1977.
The transport and fate of hydrocarbons in benthic environments.
Ph.D. Dissertation, Graduate School of Oceanography, University of Rhode Island, 175 pp.

Paul D. Boehm and James G. Quinn, 1978.
Benthic hydrocarbons of Rhode Island Sound.
Estuarine and Coastal Marine Science, Vol. 6, pp. 471-494.

9) Location of original raw data: Room 130 Horn Laboratory, GSO/URI.

10) Person to contact for data: James G. Quinn.

11) Are original data computerized: No.

12) Not applicable.

13) Not applicable.

14) Not applicable.

15) Data quality: See methods sections of published data.

16) Not applicable.

17) Not applicable.

18) Form filled out by: James G. Quinn

19) Date: May 1988.

9-2 (cont'd)

Rhode Island Sound
(sediment and clam samples)

Station	41° N Latitude		71° W Longitude	
	min	sec	min	sec
1 (S,C)	23	20	19	00
2 (S)	23	40	18	40
3 (S,C)	23	15	18	00
4 (S,C)	23	00	18	20
8 (S,C)	23	00	17	20
9 (S,C)	24	00	18	20
15 (S,C)	22	15	18	40
16 (S,C)	23	00	19	30
17 (S,C)	22	40	20	20
18 (S,C)	22	20	21	50
19 (S,C)	22	40	17	00
20 (S,C)	21	50	16	10
21 (S,C)	20	40	15	15
22 (C)	19	20	14	00
30 (S)	21	10	24	00
31 (S)	20	15	26	40
33 (C)	20	20	32	10
40 (S)	26	20	25	00
43 (S)	24	20	24	00
44 (S,C)	24	50	21	40
45 (S)	25	15	18	40
46 (S,C)	26	10	22	00
50 (S)	23	40	25	40

Reprinted from *Estuarine and Coastal Marine Science* (1978) **6**, 471–494

Benthic Hydrocarbons of Rhode Island Sound

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Received 16 March 1977

Keywords: hydrocarbons; dredge spoil; benthic environment; benthic organisms; sediments; sediment cores; PCB compounds; Rhode Island Sound

The hydrocarbon contents of surface sediments, sediment cores and ocean quahogs (*Arctica islandica*) from Rhode Island Sound have been determined. Hydrocarbon concentrations in surface sediments normally range from 1·0 to 56·1 µg/g, largely dependent on sediment type and sedimentation rates. However, concentrations up to 301 µg/g are observed in surface samples from a dredge spoil deposit located in the study area. Based on (1) qualitative and quantitative hydrocarbon distributions in the sediments, (2) the hydrocarbon to organic carbon ratio, and (3) the ratio of the concentration of a prominent cycloalkene compound to organic carbon, the normal hydrocarbon geochemistry of the region is defined. Using these criteria, the effect of the dredge spoil deposit (containing 5 to 20×10^3 metric tons of hydrocarbons) is seen to be insignificant beyond 2 km from the disposal site.

Hydrocarbon contents of the ocean quahog do not reflect the sediment distributions qualitatively or quantitatively. Throughout the study area the clams' hydrocarbon contents vary by a factor of 2·5 (2·6–6·4 µg/g wet) while the sediment concentrations vary by two orders of magnitude. The hydrocarbon assemblage in the clams exhibits a lower boiling point distribution than that in the sediments.

Key components of the surface sediments are two cycloalkene compounds of molecular weight 344 and 348. Their concentration covaries very significantly with the organic carbon content of the sediment. A major component of *Arctica* is another related cycloalkene of molecular weight 342. This compound is not present in the sediment.

A sediment core from the area shows a decreasing concentration of hydrocarbons and a decreasing percentage of unresolved components (UCM) with increasing depth. It is proposed that the rapid increase in the quantity of the UCM observed at a certain depth within the sediment, can serve as a chemical marker in the recent sedimentary record. This marker corresponds to the increased usage of petroleum products at the end of the 19th century.

Introduction

Rhode Island Sound is that region of coastal water separating Narragansett Bay from the open waters of the Atlantic Ocean. It is bounded on the west by Block Island Sound and on the east by Buzzards Bay and Vineyard Sound (Figure 1). Between December 1967 and

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[a] Present address: Energy Resources Company, Inc., 185 Alewife Brook Parkway, Cambridge, Massachusetts 02138, U.S.A.

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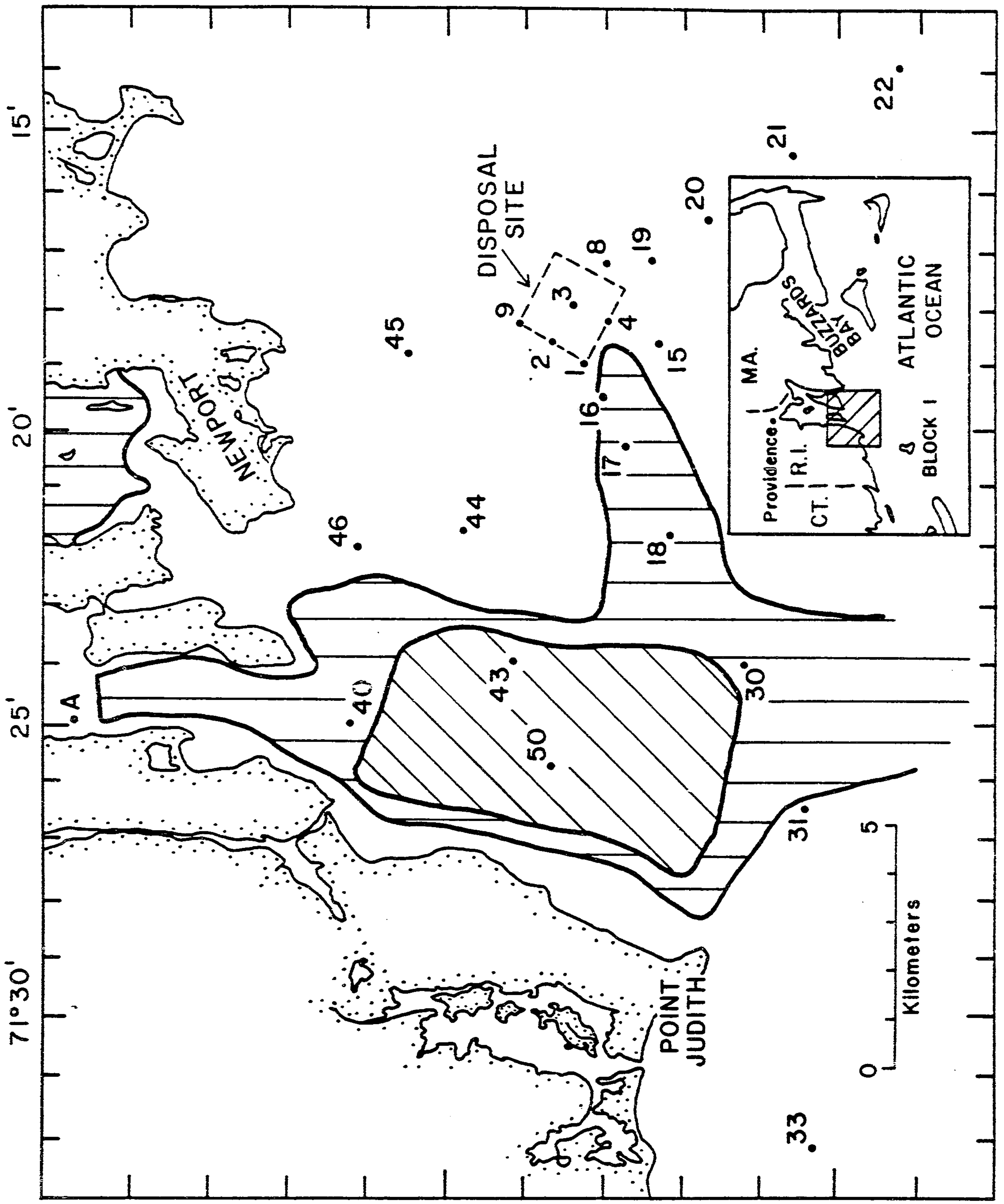
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BUZZARDS BAY
ATLANTIC OCEAN
BLOCK I

Table 1. Hydrocarbon content of Rhode Island Sound surface sediments.

Station no.	Total hydrocarbons (μg/g dry weight)	Organic Carbon (mg/g dry wt.)	% UCM	HC_{344} (μg/g dry)
1 (0-4 cm)	18.4	--	--	
1 (4-8 cm)	184	11.0	86.1	0.13
2	116	5.62	95.0	0.27
3	53.5	4.51	92.6	0.58
4	301	8.65	97.0	1.01
8	21.0	1.55	86.5	0.65
9	104	5.24	94.0	1.51
15	46.1	3.13	92.0	1.19
16	96.2	3.76	95.0	1.04
17	43.9	4.90	89.0	1.38
18	22.9	3.75	90.0	1.01
19	21.1	3.60	89.5	1.01
20	4.0	0.20	86.0	0.10
21	1.0	0.72	72.5	0.03
30	29.7	3.54	93.4	1.03
31	7.6	0.88	91.2	0.19
40	56.1	5.36	90.5	1.51
43	27.1	4.65	85.5	1.08
44	20.8	2.12	91.0	0.88
45	46.8	3.73	91.1	0.94
46	13.9	2.38	91.0	0.69
50	51.2	5.79	92.5	1.55

UCM = unresolved complex mixture of hydrocarbons.

Table 4 Hydrocarbon Content of Rhode Island Sound Sediment Cores .

(Dry weight basis)

Core No.[1]	Total Hydrocarbons (µg/g)	%UCM[2]	n-$C_{25,27,29,31}$ (µg/g)	HC 344 (µg/g)	Organic Carbon (mg/g)	PCB (ng/g)
17: 0-8	38.5	93.8	0.483	1.49	3.50	8.5
17: 8-18	21.1	93.4	0.445	0.51	2.49	3.1
17: 18-28	4.6	79.7	0.340	0.24	2.51	nd
17: 28-38	2.4	38.8	0.380	0.13	2.61	nd
4: 0-5	184	96.0	---	0.68	3.57	---
4: 5-15	486	98.0	---	0.44	7.33	---
4: 15-25	1100	98.0	---	nd	13.5	---
4: 25-35	2400	98.0	---	nd	13.6	---
4: 35-45	2270	98.6	---	nd	14.4	---

[1] Core No. = Station Number:Depth Range(cm)

[2] UCM = Unresolved Complex Mixture of hydrocarbons.

nd = None Detected

Table 5. Hydrocarbon concentrations in <u>Arctica islandica</u> of Rhode Island Sound.

Station	Total hydrocarbons[1] (μg/g wet weight)
1	5.75
3	5.46
4	2.95
8	6.12
9	4.04
15	2.84
16	5.32
17	5.53
18	4.57
19	3.06
20	3.62
21	2.62
22	2.88
25	2.60
33	4.05
44	6.37
46	5.52
C	6.54[2] 4.1-10.1[2,3]
A	3.50[4] 2.90[3,4]

[1] Precision for above values averages ±20%.

[2] Represents concentrations in <u>Mercenaria mercenaria</u> specimens from Narragansett Bay. For station location see Farrington and Quinn (1973a).

[3] Values from Farrington and Quinn (1973a).

[4] Represents concentrations in <u>M. mercenaria</u> specimens from Narragansett Bay. For station location see Fig. 1.

Appendix 10

Narragansett Bay Project
Historical Dataset Summary Sheet

NBP Index Number:

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1) Title: Geochemistry of hydrocarbons in Narragansett Bay sediments.

2) Summary: See abstracts of published data.

3) Variables measured: Total hydrocarbon (ug/g dry sediment), individual polycyclic aromatic hydrocarbons (ng/g dry sediment), and organic carbon (mg/g dry sediment).

4) Sampling locations: Narragansett Bay (see map for station locations).

5) Frequency of sampling: Each surface station (total of 12) was sampled once and each core station (total of 3) was sampled once, one was sampled twice.

6) Time span of data: March 1979 to September 1980.

7) Principal Investigators:
   Names: James G. Quinn and Richard J. Pruell
   Organization: Graduate School of Oceanography
   Address: University of Rhode Island
   Narragansett, Rhode Island 02882
   Telephone: (401) 792-6219
   Funding: U.S. Environmental Protection Agency (R803902030).

8) Citation for published data:

   Richard J. Pruell, 1984.
   The geochemistry of organic contaminants in Narragansett Bay sediments and the availability of the compounds to the blue mussel, <u>Mytilus edulis</u>.
   Ph.D. Dissertation, Graduate School of Oceanography, University of Rhode Island, 250 pp.

   Richard J. Pruell and James G. Quinn, 1985.
   Geochemsitry of organic contaminants in Narragansett Bay sediments.
   Estuarine Coastal and Shelf Science, Vol. 21, pp. 295-312.

9) Location of original raw data: Room 130 Horn Laboratory, GSO/URI.

10) Person to contact for data: James G. Quinn.

11) Are original data computerized: No.

12) Not applicable.

13) Not applicable.

14) Not applicable.

15) Data quality: See methods sections of published data.

16) Not applicable.

17) Not applicable.

18) Form filled out by: James G. Quinn.

19) Date: May 1988.

10-2 (cont'd)

Narragansett Bay
(sediment samples)

	41° N Latitude		71° W Longitude	
Station	min	sec	min	sec
1	48	50	23	50
2	47	35	22	50
3	45	50	22	25
4	44	35	21	40
5	43	15	21	05
6	40	00	19	40
7	37	35	22	05
8	34	30	22	25
9	24	20	24	00

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Geochemistry of Organic Contaminants in Narragansett Bay Sediments

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Organic contaminants from several different chemical classes were analyzed in surface sediments along a transect from the head to the mouth of Narragansett Bay. The chemical classes included total hydrocarbons, polycyclic aromatic hydrocarbons, substituted benzotriazoles and phthalic acid esters. Sediment concentrations of all compounds were highest in the Providence River and decreased with distance downbay. The observed decreases were approximately exponential for all compounds; however, the distances at which the concentrations decreased to one-half of their initial concentrations (half-distances) were different.

The depth distributions of these compounds in sediment cores from three locations were also investigated. A sediment core collected near the head of the bay (Conimicut Point) showed a well defined historical record of contaminant input to the bay. At a mid-bay location (North Jamestown), however, the record was smeared because of extensive bioturbation.

A sediment core collected near the mouth of the bay (Rhode Island Sound) showed a subsurface increase for all of the measured compounds. The results of detailed analyses suggest that this horizon may have been influenced by dredge spoil material originally from the head of the bay.

Introduction

Estuarine areas near industrial centers receive and retain large quantities of toxic organic contaminants. Due to the increased usage of petroleum products and advances in synthetic organic chemistry, a rapid increase in both the amount and complexity of these inputs has occurred during the past century.

Processes controlling the retention and preservation of organic contaminants in an estuary are complex. Important factors include the chemical properties of the compounds (especially their water solubility), the quantity and physical properties of suspended sediments in the receiving water, biological and photoreactivity of the compounds, and sedimentary depositional patterns. The latter includes physically controlled

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THE GEOCHEMISTRY OF ORGANIC CONTAMINANTS IN NARRAGANSETT BAY SEDIMENTS AND THE AVAILABILITY OF THESE COMPOUNDS TO THE BLUE MUSSEL, *MYTILUS EDULIS*

By

RICHARD JOSEPH PRUELL

A Dissertation Submitted in Partial Fulfillment of
the Requirements for the Degree of
Doctor of Philosophy
In
Oceanography

University of Rhode Island

1984

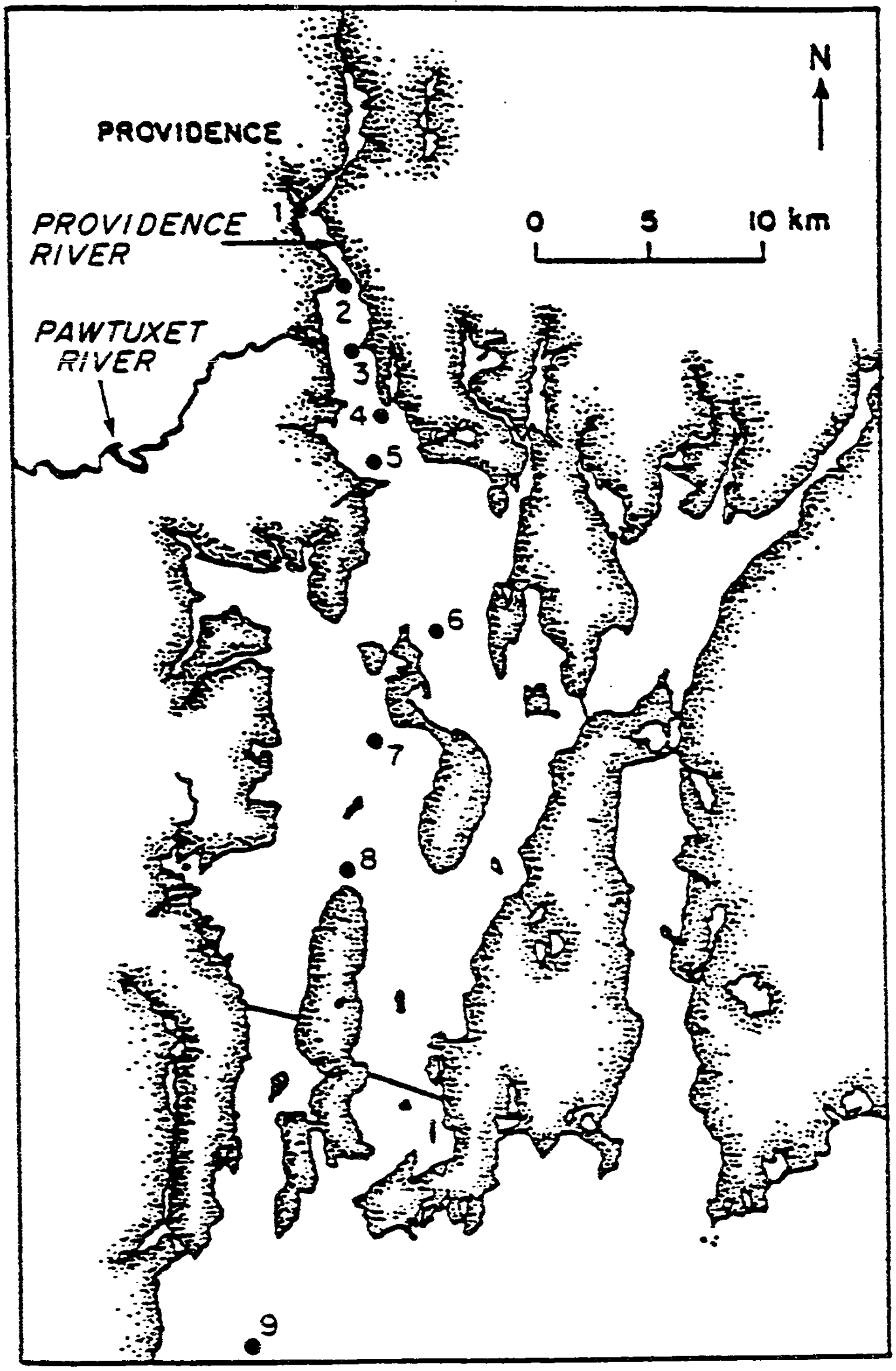
PROVIDENCE
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Table 1. Hydrocarbons and synthetic organic compounds in Narragansett Bay surface sediments.

Station Location	1 Fox Point	1a Seekonk River	2 Fields Point	3 Sabin Point	3a Pawtuxet Cove	4 Bullock Point
Naphthalene	133.9	47.6	136	38.2	44.2	50.0
2-methyl naphthalene	167.4	71.4	283	22.6	44.2	50.6
1-methyl naphthalene	93.4	75.4	125	10.6	28.2	20.4
Biphenyl	114.5	28.9	161	31.0	72.4	22.2
C_2-naphthalene	-[2]	-	-	-	-	7.68
Fluorene	347.1	811.2	70	31.0	125.3	21.0
Dibenzothiophene	243.2	391.9	61	11.0	60.0	22.6
Phenanthrene	2085	8194	659	275.9	992.2	184.6
Fluoranthene	5225	12280	867	439.4	2305	422.3
Pyrene	5332	9757	829	558.0	2161	490.3
Benz[a]anthracene	2175	4676	287	198.5	713.7	126.4
Chrysene + Triphenylene	3843	5548	579	518.9	1491	296.5
Total PAHs	19760	41880	4057 (μg/g	2135	8038	1715
Total f_1 hydrocarbons	8319	1943	2486	3131	4255	1534
Total f_2 hydrocarbons	804	390	461	411	715	78
Total f_1+f_2 hydrocarbons	9123	2333	2947	3542	4970	1612
C_{10}-benzotriazole	3.829	0.545	2.619	3.642	72.79	5.364
Chloro-benzotriazole	0.506	0.041	0.350	1.797	26.42	0.956
Di-2-ethylhexl phthalate	117.2	22.64	12.29	11.81	30.69	10.08

[1] 0-5 cm for stations 1-5; 0-2.5 cm for stations 6-9.

[2] Not determined due to interference.

Table 1. continued

Station	5	6	6a	7	8	9
Location	Conimicut Point	Ohio Ledge	Fall River	Pine Hill Point	North Jamestown	Brenton Reef
Napthalene	110	19.2	18.8	13.7	15.8	4.2
2-methyl naphthalene	71	18.7	97.3	10.5	6.3	2.9
1-methyl naphthalene	35	8.46	96.0	3.92	2.9	1.4
Biphenyl	31	15.5	65.0	5.38	4.2	1.2
C_2-naphthalene	18	4.67	25.1	1.83	1.4	0.6
Fluorene	23	18.6	41.1	4.64	6.3	2.0
Dibenzothiophene	16	5.10	23.0	2.44	4.8	2.8
Phenanthrene	208	162	393	40.0	36.3	24.1
Fluoranthene	732	260	376	73.7	50.9	33.4
Pyrene	751	626	305	95.7	44.3	31.1
Benz[a]anthracene	202	115	58.2	21.7	5.0	8.0
Chrysene + Triphenylene	316	167	56.0	64.6	16.4	10.0
Total PAHs	2513	1420	1556	338	195	122
			(µg/g)			
Total f_1 hydrocarbons	1502	612	181	345	118	46
Total f_2 hydrocarbons	209	54	23	69	5.8	1.6
Total $f_1 + f_2$ hydrocarbons	1711	666	204	414	124	48
C_{10}-benzotriazole	7.580	0.864	0.004	0.486	0.074	0.004
Chloro-benzotriazole	1.370	0.213	0.003	0.107	0.009	0.001
Di-2-ethylhexyl phthalate	3.730	2.947	0.496	1.100	0.160	0.057

Table 2. Hydrocarbons and synthetic organic compounds in a sediment core from Conimicut Point (station 5).

Sediment section (cm)	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-53
						(ng/g)					
Naphthalene	110	112	62	80	85	127	86	41	24	28	14
2-Methyl Naphthalene	71	67	47	49	64	96	66	27	17	8	6
1-Methyl Naphthalene	35	31	24	24	28	30	27	21	6	5	4
Biphenyl	31	29	16	18	28	38	27	21	9	5	5
C_2-Naphthalene	17	14	6	15	12	26	18	8	3	2	2
Fluorene	23	26	20	25	27	61	34	24	14	6	6
Dibenzothiaphene	16	17	16	18	21	21	30	10	7	3	2
Phenanthrene	208	236	206	224	164	259	215	58	75	32	27
Fluoranthene	732	633	427	461	429	563	474	198	139	70	66
Pyrene	751	700	487	541	566	640	559	209	141	70	67
B[a]anthracene	202	274	245	108	74	207	109	59	23	15	12
Chrysene + Triphenylene	316	322	377	376	358	433	214	103	36	24	30
Total PAHs	2513	2461	1934	1940	1856	2501	1859	779	494	268	241
						(µg/g)					
Total f_1 hydrocarbons	1502	1622	1539	1267	1077	758	615	211	116	47	45
Total f_2 hydrocarbons	209	276	135	126	88	81	64	15	6	5	5
Total f_1 + f_2 hydrocarbons	1711	1898	1674	1393	1165	839	679	226	122	52	50
C_{10}-benzotriazole	7.574	4.507	1.282	0.032	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Chloro-benzotriazole	1.374	1.474	5.859	0.037	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Di-2-ethyl hexyl phthalate	3.73	3.78	3.63	2.06	0.11	0.02	0.02	0.03	0.01	0.01	0.02

N.D. - not detected.

Table 3. Hydrocarbons and synthetic organic compounds in a sediment core from North Jamestown (Station 8).

Sediment section (cm)	0-2.5	2.5-5	5-7.5	7.5-10	10-12.5	12.5-15	15-17.5	17.5-20
					(ng/g)			
Naphthalene	15.8	14.4	12.5	4.3	1.2	0.6	N.D.	N.D.
2-Methyl Naphthalene	6.3	12.0	8.6	3.6	1.6	0.5	N.D.	N.D.
1-Methyl Naphthalene	2.9	4.7	3.6	1.3	0.5	0.2	N.D.	N.D.
Biphenyl	4.2	3.8	4.2	1.6	1.0	0.2	N.D.	N.D.
C_2-Naphthalenes	1.4	1.9	1.5	0.9	0.4	N.D.	N.D.	N.D.
Fluorene	6.3	5.4	4.1	1.6	1.6	0.5	N.D.	N.D.
Dibenzothiophene	4.8	6.9	1.9	1.0	0.6	0.3	N.D.	N.D.
Phenanthrene	36.3	31.7	29.1	12.9	5.0	1.1	1.5	0.7
Fluoranthene	50.9	45.5	43.6	26.0	12.3	2.2	.8	N.D.
Pyrene	44.3	41.5	38.8	13.1	11.8	4.2	1.3	N.D.
B[a]anthracene	5.0	3.7	3.6	2.5	2.3	N.D.	N.D.	N.D.
Chrysene + Triphenylene	16.4	13.8	14.4	13.1	6.2	6.4	4.7	2.3
Total PAHs	195	185	166	82	45	16	8	3
					(μg/g)			
Total f_1 hydrocarbons	118	112	77	40	15	5	3	3
Total f_2 hydrocarbons	5.8	5.8	6.0	4.1	2.6	1.7	1.4	0.7
Total f_1 + f_2 hydrocarbons	124	118	83	44	18	7	4	4
C_{10}-benzotriazole	0.074	0.061	0.035	0.019	0.004	N.D.	N.D.	N.D.
Chloro-benzotriazole	0.009	0.009	0.006	0.004	0.002	N.D.	N.D.	N.D.
Di-2-ethyl hexyl phthalate	0.160	0.077	0.071	0.045	0.033	0.048	0.027	0.020

N.D. - not detected.

Table 4. Hydrocarbons and synthetic organic compounds in sediment core #1 from Brenton Reef (Station 9).

Sediment section (cm)	0-2.5	2.5-5.0	5.0-7.5	7.5-10.0 (ng/g)	10.0-12.5	12.5-15.0	15.0-17.5	17.5-20.0
Napthalene	4.2	4.5	2.9	0.7	5.7	6.6	9.7	3.5
2-methyl naphthalene	2.9	3.6	2.8	0.6	4.3	4.9	6.0	1.8
1-methyl naphthalene	1.4	1.6	0.9	0.2	2.5	2.4	3.6	1.2
Biphenyl	1.2	1.3	0.8	0.2	2.3	1.6	2.2	0.7
C_2-naphthalene	0.6	0.5	0.3	0.1	1.2	1.0	1.1	0.5
Fluorene	2.0	3.1	2.9	0.4	4.3	3.7	5.2	2.5
Dibenzothiophene	2.8	2.6	2.5	0.3	3.4	3.2	5.0	1.3
Phenanthrene	24.1	20.9	27.5	3.4	51.2	40.0	44.3	17.6
Fluoranthene	33.4	27.8	30.1	4.6	73.7	57.5	60.1	33.4
Pyrene	31.1	19.4	22.1	3.5	54.3	42.6	46.0	25.6
Benz[a]anthracene	8.0	2.7	3.3	0.7	10.5	7.5	8.5	4.8
Chrysene + Triphenylene	10.0	4.9	5.3	0.9	18.5	14.8	12.6	5.5
Total PAHs	122	93	101	16	232	186	204	98
				(µg/g)				
Total f_1 hydrocarbons	46	26	26	16	38	32	20	14
Total f_2 hydrocarbons	1.6	1.2	1.2	0.3	2.7	2.4	2.0	1.9
Total f_1 + f_2 hydrocarbons	48	27	27	16	41	34	22	16
				(ng/g)				
C_{10}-benzotriazole	3.78	3.48	4.43	0.19	2.14	1.85	trace	trace
Chloro-benzotriazole	1.10	0.97	1.37	0.08	2.06	1.62	trace	trace
				(µg/g)				
Di-2-ethyl hexyl phthalate	0.057	0.024	0.035	0.028	0.041	0.112	0.065	0.030

Table 5. Hydrocarbons and synthetic organic compounds in sediment core #2 from Brenton Reef (Station 9).

Sediment section (cm)	0-2.5 cm	2.5-5 cm	5-7.5 cm	7.5-10 cm	10-12.5 cm	12.5-15 cm	15-17.5 cm	17.5-20 cm
Naphthalene	2.5	3.5	3.0	2.9	5.0	4.0	-	-
2-Methyl Naphthalene	1.7	3.3	3.8	3.3	3.6	3.1	0.4	0.4
1-Methyl Naphthalene	1.4	2.1	2.2	1.9	1.7	1.5	0.1	0.1
Biphenyl	0.8	1.4	1.7	1.6	1.3	1.1	0.8	0.8
C_2-Naphthalene	0.3	0.6	0.6	0.5	0.8	0.7	0.2	0.1
Fluorene	2.1	4.1	3.9	3.0	3.6	3.2	3.9	3.9
Dibenzothiophene	1.0	1.9	2.2	0.9	0.7	0.5	1.5	1.2
Phenanthrene	17.6	33.3	29.2	27.5	28.3	27.6	28.7	39.2
Fluoranthene	35.9	64.4	57.2	60.9	63.2	58.5	51.2	64.0
Pyrene	33.9	58.2	51.4	58.5	46.4	41.6	43.6	54.0
B(a)anthracene	16.0	21.4	23.7	27.0	21.8	20.8	17.9	15.1
Chrysene + Triphenylene	24.0	30.5	33.2	37.7	37.2	26.4	23.8	19.7
Total PAHs	137.2	224.7	212.1	225.7	213.6	189.0	172.1	198.5
Total f_1 hydrocarbons	37.7	61.3	54.4	(μg/g) 38.8	44.7	41.0	45.6	48.1
Total f_2 hydrocarbons	5.3	8.5	7.8	6.9(μg/g)	4.3	3.8	4.5	4.0
Total $f_1 + f_2$ hydrocarbons	43.0	69.8	62.2	45.7	49.0	44.8	50.1	52.1
C_{10}-benzotriazole	0.0105	0.0198	0.0207	0.0200	N.D.	N.D.	.0093	.0039
Chloro-benzotriazole	0.0024	0.0041	0.0084	0.0058	N.D.	N.D.	.0032	.0012
Di-2-ethyl hexyl phthalate	0.052	0.063	0.075	0.073	0.018	0.098	0.069	0.048

N.D. = not determined due to interferences.