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An Evaluation of Potential Effects of Coal Transportation and Storage on the Ecology of Norwalk Harbor

CONNECTICUT COASTAL ENERGY IMPACT PROGRAM

Submitted to:

City of Norwalk

Health Department

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Connecticut Coastal Energy Impact Program

Prepared for the City of Norwalk

and

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Connecticut Coastal Energy Impact Program

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Summary

The purpose of this project was to document the existing environmental conditions of Norwalk Harbor and to use this baseline to evaluate what future impacts might occur from the transportation and storage of coal associated with the Manresa Island Generating Plant. Basic parameters monitored were tracemetals, pH, turbidity, alkalinity, color, acidity, and others.

The concentrations of copper, zinc, nickel, manganese, and barium were determined for major components of the Norwalk Harbor Ecosystem sediments, shellfish (oysters and hard clams), benthos, and finfish.

Coal Transportation

The increased need for barge shipments to the Manresa Island Plant could result in a degradation of water quality over Norwalk's prime shellfish grounds. The increased barge traffic would increase the possibility of accidental discharges of oil and diesel fuel, spillage of coal into the harbor and increased sediment resuspension (turbidity) from tugboat operations.

These effects would be most significant during the summer months when metabolism of organisms is highest and when spawning of commercially valuable shellfish species is taking place. Oyster and clam larvae are highly susceptible to changes in water chemistry and to even slight increases in the levels of toxic substances. A significant increase in larval mortality could cause an eventual reduction in the size of shellfish populations in future years.

Coal Storage

The major impacts to Norwalk Harbor from coal storage piles would result from surface-water runoff. This runoff would contain coal fines and various concentrations of trace metals.

Shellfish

Metal levels in oysters and clams were found to be elevated which therefore resulted in their being designated as Class II shellfish. Class I is the best possible designation (lowest metal levels) and Class IV is the worst (highest metal levels). According to this system, only Class IV shellfish would have metal levels in excess of Federal guidelines and would therefore be the only class to pose a potential health hazard.

The chronic input of trace metals into the harbor ecosystem from coal pile runoff could only result in in creased levels of these toxic substances in the tissues of oysters and clams. This could, in future years, cause the shellfish to be elevated to Class III and possibly to Class IV.

Elevation of shellfish to Class IV status would cause severe restrictions in commercial and recreational harvesting. It would result in economic losses to the City of Norwalk and could pose a health problem to individuals that continue to harvest shellfish in defiance of the ban.

Sediments

The chronic input of trace metals from coal pile runoff would lead to increased concentrations in harbor sediments. Current metal levels have been shown to be elevated, especially in the inner harbor.

Through the processes of bioconcentration, bioaccumulation, and biomagnification, these metals will be transferred to the benthos and ultimately to finfish.

Benthos

The chronic input of trace metals from coal pile runoff would lead to increased levels in the tissues of benthic invertebrates. This will ultimately result in increases in the tissues of finfish species which prey upon these organisms.

Deposit feeding invertebrates like Nereis succinea will have the highest levels of trace metals because they are in direct contact with the sediment and actually ingest sediment while feeding.

Finfish

Chronic input of trace metals from coal pile runoff would ultimately lead to increased levels in the tissues of finfish. This is especially important for resident species such as the winter flounder which spend most of their time within the harbor ecosystem.

Winter flounder were found to have elevated but still not high levels of trace metals within their musculature. These levels conform to all current Federal guidelines and therefore pose absolutely no health hazard.

Additional inputs of trace metals into the harbor could ultimately raise tissue concentrations to unhealthy levels.

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I. Introduction

Norwalk Harbor is a highly productive estuarine ecosystem that supports important sport and commercial fisheries. The harbor is also an important part of the environment of urban residents and represents one of the largest remaining areas of open space in urban Norwalk. The harbor is thus the greatest potential source of recreation available to Norwalk citizens. Norwalk Harbor, therefore, has significant economic and social importance by functioning in recreation, commercial shellfishing, waste assimilation, wildlife habitation and transportation.

Urbanization has been the most important determinant of the environmental quality of coastal areas, particularly the quality of the urban environment where the vast majority of citizens live. The pollution of Norwalk Harbor has many important ramifications including human health problems, destruction of natural resources, reduction of aesthetics and interference with other uses of the coastal zone. Apart from the immediate problem of the hazard to human health from the consumption of contaminated fish and shellfish, there is a great need to establish the extent to which current levels of pollutants are doing harm to specific natural resources and to the Norwalk Harbor ecosystem in general.

The purpose of this project is to document the existing environmental condition of the outer regions of Norwalk Harbor and to use this environmental baseline to evaluate what future impacts might occur from the transportation and storage of coal associated with the Manresa Island Power Plant. Basic parameters to be monitored will be temperature, salinity, dissolved oxygen, pH, turbidity, alkalinity, acidity, color and various heavy metals. Emphasis will be placed on the extensive oyster and hard clam beds located off Manreas Island.

II. Objectives

A. To establish an environmental baseline in the outer areas of Norwalk Harbor:

1. temperature
2. salinity
3. dissolved oxygen
4. pH
5. turbidity
6. color
7. alkalinity
8. acidity
9. ammonia
10. chlorine
11. nitrates
12. phosphates

B. To establish a baseline of trace metal levels in:

1. sediments
2. benthos
3. shellfish
4. finfish

C. To use this baseline to predict what impacts coal conversion would have on environmental conditions within the Harbor.

D. To evaluate to what extent heavy metal increases would affect:

1. oyster industry
2. recreational clamming
3. sport fishing

E. To evaluate if increases in heavy metal levels would pose any dangers to human health.

III. Norwalk Harbor

Norwalk Harbor (Figure 1) is located on the north shore of Long Island Sound, 13 miles southwest of Bridgeport Harbor, and 41 miles east of New York City. The harbor is comprised of the Outer Harbor, also knows as the Sheffield Island Harbor, and the tidal portion of the Norwalk River. For purposes of this study the harbor has been further divided into three characteristic areas. The Inner Harbor area, with a natural depth not more

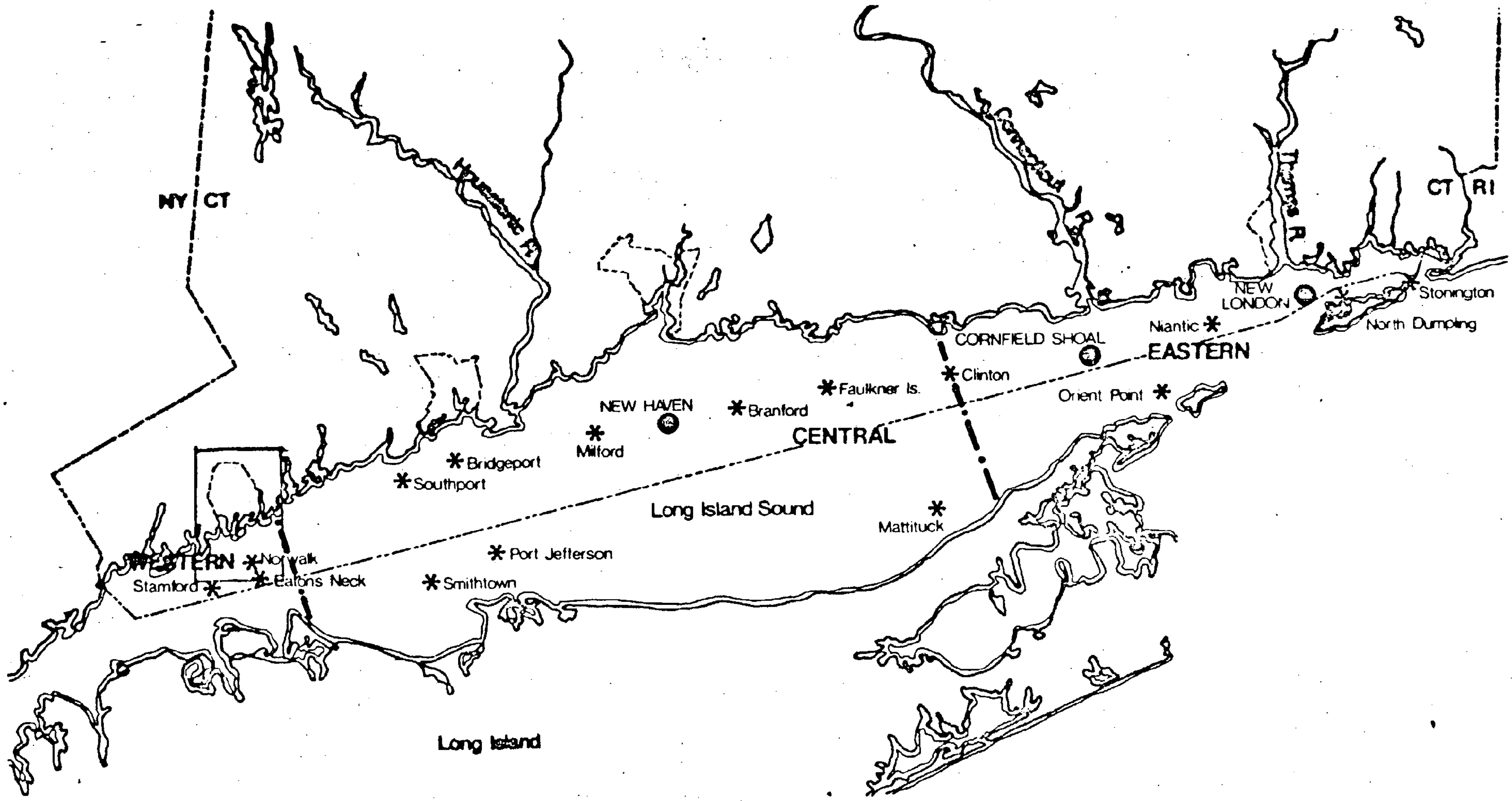

Figure 1. Geographic Location of Norwalk Harbor.

than 2 feet at mean low water extends from the tidal portion of the Norwalk River, southerly to a line between Fitch Pt. and Shorefront Park, where it meets the Middle Harbor area. The Middle Harbor maintains an average width of 0.5 miles and a range of depths from 2 to 8 feet at mean low water. The Middle Harbor area is bordered to the south by the Outer Harbor along a line of small islands running from the southwest (off the point of Manresa Island), to the northeast, off Calf Pasture Beach. The Outer Harbor area run southwesterly to include the area of Sheffield Harbor. The natural depths in this area range from 6 to 30 feet at mean low water. Mean tidal range in the harbor is 7.1 feet, and the spring range is 8.4 feet (Army Corps of Eng. 1979).

The current direction in Norwalk Harbor is from the southwest in Long Island Sound into the harbor during a flood tide and opposite in ebb tide. Current velocities reach a maximum of 0.7 knots at flood and 0.8 at ebb off Calf Pasture Pt. approximately 3 hours after low and high slack water respectively. The major portion of the Middle and Inner harbor areas experience only weak currents primarily due to the buffer zone created by the Norwalk Islands, situated 1 to 2 miles offshore and extending for a distance of about 6 miles.

Climatic conditions of the area show the mean annual temperature to be 51^{o}F (10.5^{o}C) with January mean temperatures ranging from 22 to 38^{o}F (-5.5 to 3.3^{o}C) and July ranges from 62 to 84^{o}F (16.6 to 28.8^{o}C). The mean annual rainfall is between 44 and 48 inches (111.8 to 121.9 cm) with a snowfall mean of 30 inches (76.2 cm) (SWRPA, 1976).

The City of Norwalk covers an area of 30.4 square miles and essentially surrounds the harbor. In addition to the city proper, harbor land areas include the communities of East Norwalk, South Norwalk, and the Outlying Norwalk Islands. The majority of these harbor shore areas in Norwalk, except for the commercial center, are residential, with 26% of the shoreline classified as such. The total residential acreage on the immediate coastline is 995 of a total 2545 acres on the water. Undeveloped property (518 ac. 8.41 mi.) is the next largest coastal use category as determined by the South West Regional Planning Agency (SWRPA Tech Rep. #21A 1976). In comparison with neighboring towns, Norwalk compares favorable in the category of coastline opened to the public or undeveloped, with some 2.2 miles of coastline so designated. There are two large city parks on the harbor, in addition to the Norwalk Islands for use as recreational areas.

The population of Norwalk has increased from 67,776 in 1960 to 79,113 in 1970 with a projected increase of 11% in the 1970 decade (SWRPA, 1976). The city is an important industrial center as well as the trading center for nearby towns. Principal industries include the manufacture of heating and air conditioning equipment, air compressors, pumps, electrical equipment, data processing equipment, machine tools, optical equipment, plastics, and clothing.

As a major economic center, Norwalk Harbor has considerable deep draft traffic which is primarily composed of shipments of petroleum products. During 1975, 2720 (inbound and outbound) trips by vessels with drafts up to 17 feet were recorded. These vessels carried 847,490 short tons of petroleum, sand, and gravel. The latest figures (1977) show a drop in commercial vessel tonnage to 822,908 short tons, partially due to shoaling (Army Corps of Eng. 1979).

The harbor accommodates a substantial recreational fleet. More than 2600 pleasure boats with drafts up to 9 feet are based at the harbor's 8 yacht clubs and 14 marinas. During the summer months the local boat launching ramps are utilized by some 500 boats. Additionally, about 500 transient vessels visit Norwalk Harbor annually.

Norwalk Harbor currently sustains the largest commercial oyster fishery in Connecticut with over 2,000 acreas of leased oyster grounds occurring in the mouth of the harbor (Figures 3 and 4). Three local oyster companies accounted for 3,500 tons of shellfish cargo into the harbor in 1975. Oysters are an important economic as well as cultural asset to the city. One of Norwalk's earliest and best known industries was shellfishing, and a conservative 1971 estimate by the EPA stated that the Norwalk estuary still produces over one million dollars worth of shellfish annually.

Clamming is also an important recreational activity in Norwalk with over 1,000 permits being issued annually. Sportfishing is also a valuable form of recreation as shown by the over 2,500 boats registered in Norwalk. It is evident, therefore, that these marine activities have an important recreational and economic bearing on the City of Norwalk.

IV. Environmental Effects of Coal on Coastal Ecosystems: Review

This review is taken largely from Dvorak and Lewis, 1978; Davey, 1976; and United Nations (GESAMP), 1976.

Coal is probably the first of the fossil fuels to be used for energy. It was recognized as an energy source by the Chinese around 1100 B.C., while the ancient Greeks were probably the first of the Western cultures to be aware of coal. The first known coal mines in North America were operated by the Hopi Indians of Arizona some 200 years before Columbus.

Coal occurs mainly in the north temperate regions of the earth. Small deposits are located at the poles but there is almost none in the tropics. The bulk of the deposits are located in North America (50%) while significant amounts are found in the USSR (20%) and Asia (15%).

Coal was formed from the debris of giant tree ferns and other vegetation that was growing in swamps and bogs 300 million years ago. When the plants died they were covered with sediment that prevented their oxidation by atmospheric oxygen. Further build up of sediment and other geologic processes subjected these materials to high pressures that resulted in their conversion to coal.

Coal is composed of a highly complex and heterogeneous group of substances (Table 1) and possesses a wide range of chemicals. The two most environmentally important components of coal are trace metals and radionuclides.

Trace metals are generally defined as those with a relative abundance in the earth's crust of 0.1% or less. Trace elements are essential to all life systems yet excess amounts are toxic. Estuarine systems are not uniformly mixed and lack of uniform dilution can cause local concentrations of metals. Some metals discharged even in small quantities can be accumulated to alarming levels by certain marina biota. Sea foods harvested by man can become extensively impacted when excessive metals are added to the sea.

Coal Transportation

Any conversion of the Manresa Island Power Plant from oil to coal may require frequent barge shipments of coal into Norwalk Harbor. A conversion will also necessitate the storage of large amounts of coal on Manresa Island. The extensive barge traffic resulting from coal conversion could have potentially significant effects on the environment of outer Norwalk Harbor. These environmental impacts could result from chronic spills of coal into Norwalk Harbor, rain water washing off the coal into the harbor and from spills associated with increased tugboat traffic.

These environmental alterations would have greatest impact during the summer spawning season of oysters and hard clams. Shellfish larvae are highly susceptible to even slight changes in water chemistry.

Coal Storage

Coal storage areas are needed to maintain a continuous supply between shipments. There are two general types of coal storage: live storage and reserve storage. The live storage stockpile serves as the buffer between the furnace's continuous demand and the intermittent arrivals of bulk shipments. Reserve storage is held in reserve in case the periodic shipments are interrupted.

Assuming there is a daily arrival of coal shipments, the minimum size of the live storage pile would be the amount of coal consumed per day by the plant. For the Norwalk Generating Station this would be 2,800 tons per day when operating at full load. Usually the live storage pile must be larger because coal shipments do not arrive at precisely the same time each day.

The reserve storage usually consists of a 100-day coal supply. For the Norwalk plant the 100 day supply would be 280,000 tons.

Coal storage piles on Manresa Island could therefore affect the outer harbor ecosystem from surface water runoff. This runoff would contain concentrations of toxic materials. The water chemistry over Norwalk's valuable oyster grounds could be altered by increasing the concentration of toxic heavy metals and by causing changes in pH, turbidity, dissolved solids, acidity and alkalinity.

The most serious potential environmental consequence of coal storage is the elevation of trace metals in the sediments, shellfish, finfish and benthos of Norwalk Harbor.

In estuarine systems like Norwalk Harbor trace elements are predominately associated with the sediments which act as both a sink and reservoir with relatively small amounts fould dissolved in the water. Trace elements enter aquatic systems either by direct discharge or indirect input (groundwater, terrestrial litter, runoff and atmospheric fallout).

Trace elements in aquatic systems undergo differential uptake by the biota. Bioaccumulation (the ability of an organism to concentrate an element above abiotic environmental levels); bioconcentration (the influence of size on the pattern of elemental concentration within an organism); and biomagnification (the tendency for trace elements to be concentrated with trophic level transfer) are three topics of concern in evaluating the environmental effects of coal conversion.

Sublethal effects of trace elements on invertebrates, shellfish and finfish are probably more significant to the ecosystem than acute toxic effects. Sublethal concentrations of trace metals can reduce the fitness of an organism by changes in physiology, shell deposition, growth, development and reproduction. Sublethal concentrations can also effect the population of community level by reductions in abundance, diversity and production.

The Environmental Contaminants Division of the U.S. Fish and Wildlife Service stated in a recent publication entitled, "Impacts of Coal-Fired Power Plants on Fish, Wildlife and Their Habitats" that "In assessing trace-element loading to aquatic systems from coal combustion, it is important that the quality of water which may receive particulate emissions be assessed." It is essential that a preconversion baseline of heavy metal levels and environmental parameters be established for Norwalk Harbor so that long-term impacts of conversion from oil to coal can be evaluated. This is extremely important for industrial harbors like Norwalk where additions of heavy metals from coal conversion may result in concentrations exceeding acceptable values.

V. Sampling Stations

King	- Station 1
STP	- Station 2
Shorefront Park	- Station 3
Buoy 19	- Station 4
Buoy 17	- Station 5
Buoy 7	- Station 6
Sheffield Harbor	- Station 7

The location of the sampling stations can be found in Figure 2. The inner harbor is composed of Stations 1B, 1 and 2; the middle harbor, Stations 3 and 4; and the outer harbor, Stations 5 and 6.

Station #6 is located off Buoy #7 off Manresa Island where the Generating Station is located.

VI. Trace Metals

Methods

Any and all materials, either directly or indirectly connected with the experiment, were washed with 10% nitric acid and rinsed three times with de-ionized water. This includes dissecting instruments, all glassware, and electrodes. This procedure removes any endemic trace metals from the material being used and prevents contamination of the samples.

A small portion (0.5 gm.) of tissue was removed from the organism of interest and washed with de-ionized water. It was then placed in a clean, acid washed, glass tube that was previously weighed to the nearest hundred-thousandth of a gram using a Mettler H51 analytical balance. All tubes were then placed in blocks and heated on a hot plate for 45 to 90 minutes until the tissue was completely dry. After the tubes had cooled, they were again weighed and the dry tissue weight obtained by subtracting the empty tube weights.

The dried tissue was prepared for analysis by digesting in 0.5-1.0

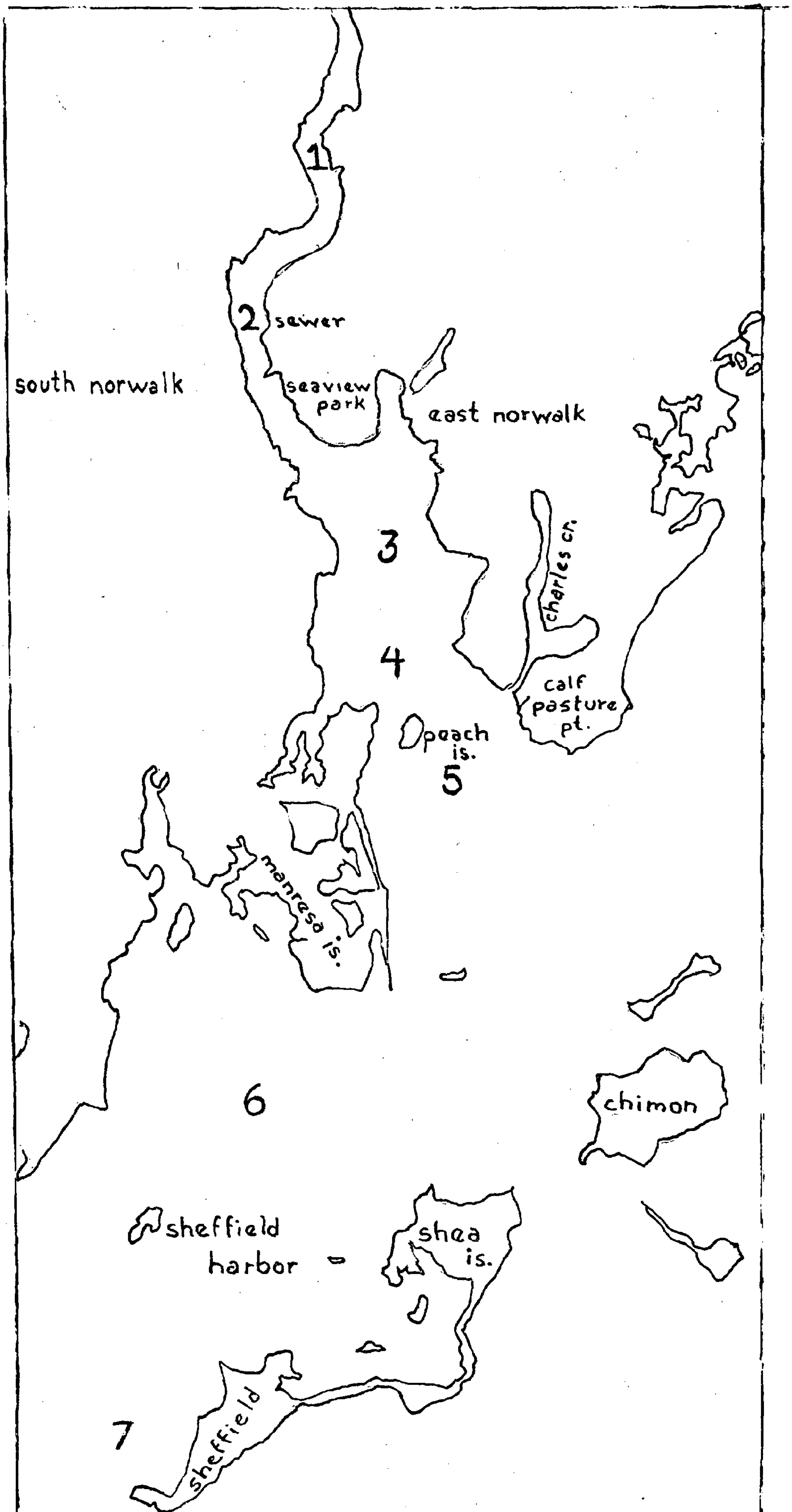

Figure 2
Norwalk Harbor
Sampling Stations

TABLE 1 . Trace Element Constituents of Coal (from Dvorak et al, (1977).

Element	Coal (ppm)
Antimony	0.08
Arsenic	0.87
Barium	440.0
Beryllium	0.29
Boron	37.7
Cadmium	0.11
Chromium	1.8
Copper	5.2
Fluorine	78.5
Germanium	0.48
Lead	0.15
Manganese	26.2
Mercury	0.131
Molybdenum	3.67
Nickel	3.67
Selenium	0.98
Vanadium	13.0
Zinc	16.2

mls acid mix consisting of ultrapure perchloric, sulfuric, and nitric acids in the ratio of 24:24:1.5 hours until the acid was colorless indicating complete digestion. After the acid has cooled, 3.0 mls of de-ionized water is added to the tubes and this solution transferred to 50 ml. plastic tubes and brought to volume with de-ionized water.

The solutions are then analyzed for specific trace metals by atomic absorption spectrophotometry (Perkin-Elmer Model 370).

A. Shellfish

The following trace metals were examined in oyster and hard clam tissues: Copper, Zinc, Nickel, Manganese and Barium. These elements were chosen because of their high concentrations in coal (Table 1).

Only the gill tissue of oysters and clams was examined.

Copper

Although not abundant, copper is widely distributed in crustal rocks with an overall abundance of 45 ppm. Copper reaches the marine environment from industrial wastes, burning of coal and oil and sewage effluents. The toxicity of copper and copper sulfate to aquatic organisms varies considerably and is dependent on such factors as temperature, turbidity and pH. Larvae are consistently more sensitive to copper than adults. In many molluscs and polychaetes there appears to be no regulation and concentration factors of 100-1000s are common.

Typical levels of copper in fish appear to be of the order of 20 ppm while shellfish yield higher values.

Nickel

Nickel compounds are only moderately toxic to aquatic organisms. The principle industrial use of nickel is an an alloying element both in steels and stainless steel. Nickel is concentrated from sea water by many marine organisms, e.g., oysters and clams by a factor of about 4000.

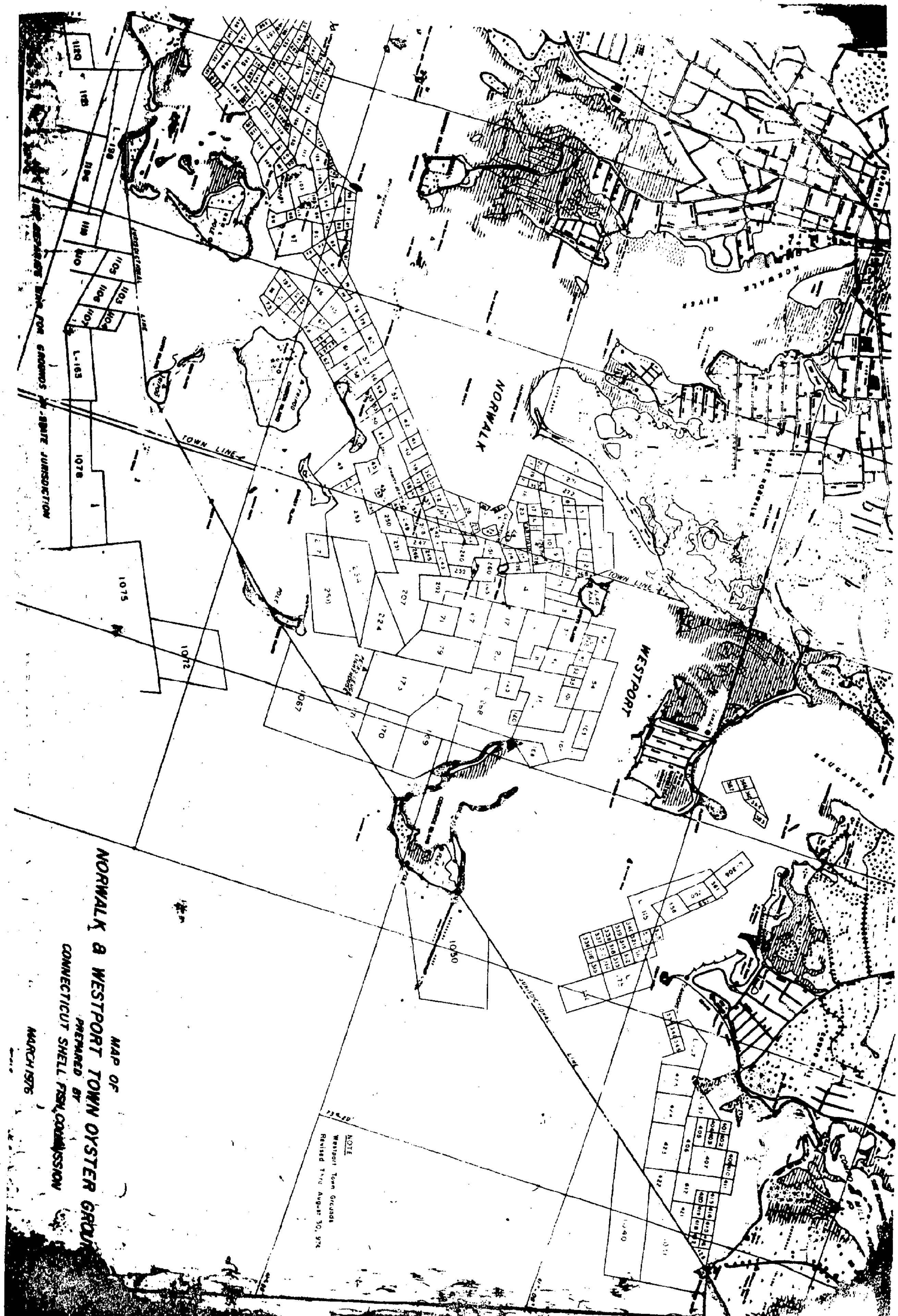
MAP OF
NORWALK & WESTPORT TOWN OYSTER GROU
PREPARED BY
CONNECTICUT SHELL FISH COMMISSION
MARCH 1976
NOTE
Westport Town Grounds
Revised Thru August 30, 1974
NORWALK
WESTPORT
TOWN LINE
NORWALK RIVER
SAUGATUCK
EAST NORWALK

TABLE 2. Average Trace Element Concentrations (ppm) of Major Age Classes of Oysters from Norwalk Harbor.

Trace Element: Age Class	Copper	Manganese	Zinc	Nickel	Barium
2 years	742.4	161.8	5,469.3	1,233.7	—
	(213.9)	(100.1)	(1,378.8)	(631.5)	
3 years	1,066.7	121.0	4,988.9	1,413.7	—
	(546.9)	(36.4)	(1,726.1)	(723.3)	—
4 years	1,171.1	159.9	5,922.3	937.9	—
	(787.4)	(50.4)	(2,934.8)	(350.7)	
5 years	709.7	321.1	6,327.8	856.8	—
	(444.8)	(341.8)	(3,046.2)	(72.4)	
>6 years	1,350.3	154.4	8,207.3	1,083.2	—
	(1,003.1)	(61.5)	(5,252.2)	(637.9)	
Total for all Oysters	1,049.4	174.9	6,180.1	1,143.7	2,291.6
	(682.3)	(120.2)	(3,204.6)	(583.9)	(707.6)

*Standard deviation given in parentheses.

Zinc

Large amounts of zinc are discharged into rivers in industrial wastes and sewage effluents. Concentration factors for zinc in marine organisms range from 2,000-100,000 depending upon the species with lowest values derived from fish and highest from oysters.

Manganese

Manganese is used extensively as an alloying element for steel and large quantities are used in the production of dry batteries, glazes for pottery, making colored bricks, dyes, pigments, catalysists and intermediates. Rivers deposit most of the manganese, which is deposited as manganese dioxide or manganese nodules on the ocean floor. Average concentrations of manganese for the Northern Quohaug (Mercenaria mercenaria) are reported as 3-7 mg/kg; for surf clams (Spisula solidissima) 0.68-2.79 mg/kg. Manganese occurs at low concentrations in seafoods and does not at the present time present a health hazard.

Oysters (Crassostrea virginica) were collected in leased oyster grounds in the outer region of Norwalk Harbor (Figure 3). Oysters were measured (Length of Shell) and grouped into major age categories based on past growth studies done in Long Island Sound.

Total mean values for all oysters (Table 2) show zinc ($\overline{X}$ = 6,180.1 ppm) and Barium ($\overline{X}$ = 2,291.6 ppm) to be present in highest concentrations while Manganese ($\overline{X}$ = 174.9 ppm) exhibited the lowest values. Copper ($\overline{X}$ = 1,049.4 ppm) and Nickel ($\overline{X}$ = 1,143.7 ppm) exhibited intermediate levels.

Copper levels were highest in $>$ 6 year olds achieving a mean of 1,350.3 ppm and lowest in 5 year olds ($\overline{X}$ = 709.7 ppm) and 2 year olds ($\overline{X}$ = 742.4 ppm). Three and four year olds achieved intermediate levels of $\overline{X}$ = 1,066.7 ppm and $\overline{X}$ = 1,171.1 ppm respectively.

Manganese was found in highest concentrations in 5 year olds ($\overline{X}$ = 321.1 ppm) and lowest levels in 3 year olds ($\overline{X}$ = 121.0 ppm). Zinc concentrations were highest in 6 year olds ($\overline{X}$ = 8,207.3 ppm) and lowest in 3 year olds ($\overline{X}$ = 4,988.9 ppm). Nickel showed an unusual distribution having highest levels in 2 ($\overline{X}$ = 1,233.7 ppm), 3 ($\overline{X}$ = 1,413.7 ppm) and 6 year olds ($\overline{X}$ = 1,083.2 ppm) and lowest levels in 5 year olds ($\overline{X}$ = 856.8 ppm).

Oysters were also examined from the Saugatuck River, Westport (Figure 3) to obtain comparative trace metal data (Table 3). Zinc showed higher values ($\overline{X}$ = 8,055.1 ppm), Copper ($\overline{X}$ = 843.9 ppm) and Manganese ($\overline{X}$ = 98.9 ppm) slightly lower values and Nickel ($\overline{X}$ = 439.9 ppm) considerably lower readings.

A characteristic of filter feeding organisms, especially oysters, is their ability to concentrate a variety of compounds from the surrounding water. Many substances, though not necessarily harming the organism, concentrate in the animal's tissues (Huggett, et al., 1973). Kopfler and Mayer (1969), have demonstrated that oysters are able to concentrate cadmium, copper, and zinc four to five orders of magnitude above that of the surrounding water. Several investigators (Fitzgerald, et al., 1963; Kopfler, et al., 1969) have shown that oysters from the same area may vary in their metal concentrations as much as 100%; some as high as 300%. These results have been repeated for oysters all along the Atlantic coast. A recent study (Huggett, et al., 1973) of metal levels in oysters indicate a natural concentration exist which is a function of, or is measured by, salinity. Animals living in fresher waters consistently contained more copper and zinc than those from a more saline environment; the chemistry of which has been described elsewhere (Huggett, et al., 1975).

Hard clams (Mercenaria mercenaira) were collected from outer Norwalk Harbor using a hydraulic clam dredge (Figure 3). All clams were greater than 9.0 cm (Shell length) which places them in the older quahog size

TABLE 3. Average Trace Element Concentrations (ppm) of Hard Clams and Slipper Shells (Norwalk) and Oysters (Saugatuck River, Westport).

Trace Element: Species	Copper	Manganese	Zinc	Nickel	Barium
Mercenaria mercenaria	66.3	318.7	410.5	345.2	12,504.9
(Hard Clam)	(99.5)	(629.5)	(610.8)	(237.5)	(929.6)
Crepidula fornicata	32.8	161.5	132.7	200.4	—
(Slipper Shell)					
Crassostrea virginica	843.9	98.9	8,055.1	439.9	—
(Oyster)	(334.2)	(8.84)	(1,583.3)	(62.7)	
Saugatuck River, Westport					

*Standard deviation given in parentheses.

category. Trace metal levels for Mercenaria are summarized in Table 3. All metal values except Barium and Manganese exhibited reduced levels when compared with Crassostrea.

Barium exhibited the highest levels ($\overline{X}$ = 12,504.9 ppm) while copper the lowest ($\overline{X}$ = 66.3 ppm). Zinc declined from 6,180.1 ppm in the oyster to 410.5 ppm and Nickel from 1,143.7 ppm to 345.2 ppm. Manganese showed increased levels ($\overline{X}$ = 318.7 ppm) in the hard clam when compared to the oyster.

The Slipper Shell (Crepidula fornicata) which were attached to the Norwalk oysters were also examined for trace metals (Table 3) (Gill tissue only). Crepidula is a suspension feeder that feeds in a manner comparable to the oyster and clam. Crepidula exhibited lower overall levels of trace metals with Nickel ($\overline{X}$ = 200.4 ppm) being the highest and Copper ($\overline{X}$ = 32.8 ppm) the lowest.

The trace metal values for Norwalk shellfish are not unusual for urban coastal areas. Feng and Rudy (1973) surveyed the uptake of metals in oysters from various Connecticut areas from Noank to Norwalk. They found that New Haven, New London and Noank generally had the lowest concentrations while Bridgeport and the Housatonic River had the highest values. Norwalk oysters tended to have concentrations that were intermediate between the two groups but were closer to the Noank, New London, New Haven group. Wong (1975) also evaluated trace metal levels for oysters and clams from several Connecticut areas. He found the Housatonic River to have the highest metal values.

All metals inventoried during this study showed increases over those of Feng and Wong.

I have established the following four general Groups for overall trace metal levels in shellfish:

Class I - low Levels
Class II - elevated Levels
Class III - highly elevated Levels
Class IV - extremely High (toxic) Levels

Based on this calssification Norwalk shellfish would fall into the Class II category. Shellfish placed in Class I, Class II and Class III categories would be within all acceptable Federal toxic substance guidelines and would pose no health hazard to humans.

B. Finfish

Uptake of trace elements by fish occurs primarily through two routes: (1) active or passive absorption through the gills and (2) ingestion. The major source of trace elements accumulated by fish is believed to be from ingestion of contaminated food species. Bioconcentration and Biomagnification of trace metals by commercial and recreational finfish species pose potential problems to humans.

The public health significance of any trace metal in fish depends to a large degree on the chemical form of the metal and its biological utilization. If an element is present in fish either in a form that is relatively non-toxic and/or has a low biological utilization potential, the contaminant may be of little consequence from a public health standpoint.

Metal concentrations from the dorsal musculature of two demersal species were examined: Winter flounder, Pseudopleuronectes americanus and the sand dab Scopthalmus aquosus. These species were chosen because they are fairly permanent residents of the Norwalk Harbor ecosystem and therefore would reflect local metal levels and not those obtained from a distant Estuarine system. These metal values are summarized in Table 4.

Winter flounder were collected from both inner harbor and outer harbor regions. There was no significant difference in metal values between these two areas.

TABLE 4. Average Trace Element Concentrations (ppm) of Finfish Species from Norwalk Harbor.

Trace Element: Species	Copper	Manganese	Zinc	Nickel	Barium
Winter Flounder (Inner Harbor)	7.9 (2.1)	19.4 (2.6)	43.3 (5.75)	137.9 (21.9)	—
Winter Flounder (Outer Harbor)	8.0 (2.9)	22.3 (5.2)	50.2 (9.9)	160.3 (28.9)	2,345.6
Sand Dab (Outer Harbor)	6.7 (0.9)	17.4 (2.4)	40.8 (5.6)	129.3 (16.9)	—

*Standard deviation given in parentheses.

TABLE 23. Trace Element Concentrations (ppm) in Norwalk Harbor Sediments.

Trace Element: Station Number	Copper	Manganese	Zinc	Nickel
1	299.0	291.0	672.0	0
2	349.2	226.0	299.3	0
3	196.2	309.0	218.0	31.0
4	50.2	241.0	85.0	0
5	59.4	214.0	105.0	0
6	62.4	236.4	93.1	0
7	73.0	280.0	104.0	2.2

Barium ($\overline{X}$ = 2,345.6 ppm) exhibited the highest values and copper ($\overline{X}$ = 8.0 ppm) the lowest. The sand dab exhibited slightly lower values than the winter flounder with Nickel being the highest ($\overline{X}$ = 129.3 ppm) (Barium was not determined) and copper again the lowest ($\overline{X}$ = 6.7 ppm).

The dab and the winter flounder feed almost exclusively on benthic invertebrates such as polychaetes, bivalves and amphipods. As metal levels rise in the tissues of these prey species, it will cause a subsequent rise in the tissue of their finfish predators.

Lamb (1975) conducted an extensive inventory of trace metal levels in finfish throughout the country and found the majority of species tested to have Copper levels of 0.0-0.6 ppm, Zinc levels of 2.0 to 6.0 ppm; Nickel levels of 0.1 to 0.3 ppm and Manganese levels of 0.1 to 0.2 ppm.

C. Sediments

Table (23) summarizes the metal concentrations for each element from inner, middle and outer harbor areas. Sediment metal levels showed a general decrease from the inner harbor areas seaward to Long Island Sound. At most stations Manganese occurred in greatest concentrations with Zinc, Copper and Nickel being less important.

By periodically analyzing the sediments in the harbor, comparisons can be made against this initial baseline study to monitor fluctuations in the heavy metal load of the system.

The higher metal concentrations in the inner harbor coincide with the fine silty/mud found in this area, whereas decreases in concentration towards the outer harbor may relate to the silty/sand deposits in those areas. Cross, et al. (1970), found that the finer sediments of estuaries stay in suspension longer and, therefore, increase the opportunity for particulate material and water to exchange and redistribute metals. In Norwalk Harbor, as the mud fraction of the sediment decreased seaward so

TABLE 24. Trace Element Concentrations (ppm) in Guilford Harbor Sediments.

Trace Element: / Station	Copper	Manganese	Zinc	Nickel
Buoy C-3	129.0	783.2	177.0	46.5
Off - #5 St.	70.4	754.0	104.0	47.1
Station 3 (Shell)	45.1	239.0	72.0	21.2
Station 1 (Faulkner Island)	15.0	166.0	58.1	21.2

TABLE 25. Average Trace Element Concentrations (ppm) for <u>Nereis succinea</u> from Norwalk Harbor.

Trace Element: Harbor Region	Copper	Manganese	Zinc	Nickel
Inner	300.9	246.3	450.8	565.9
Middle	235.9	141.5	505.4	289.8
Outer	253.4	328.9	307.2	423.8

did the concentration of metals associated with it. Stoffers, et al. (1977), documented a similar occurrence for New Bedford Harbor.

It has been shown that wastewater treatment plants contribute sus-stantial amounts of copper, lead, zinc, cobalt, iron, and manganese to discharge locations. Further, they have been pinpointed as major contributors of cadmium, chromium, and nickel (Cross and Duke, 1974). The industrialized nature of the inner harbor may also be responsible for the additions of iron, copper, and zinc to the system.

An analysis of metal levels from Guilford Harbor sediments (Table 24) is included for comparative purposes.

D. Benthic Invertebrates

Trace metal uptake by invertebrates depends primarily upon metabolism and the feeding behavior of the organism as well as the form of the trace element in the environment. The concentration of trace metals in the tissues of benthic invertebrates is an important step in their transfer to the tissues of finfish and ultimately to man.

Many invertebrate species are deposit feeders and obtain their nourishment by direct ingestion of sediments. This provides a direct pathway for the transferral of metals from the sediments to animal tissues.

Nereis succinea, a deposit feeding polychaete, was chosen as the best trace metal indicator species for the Norwalk Harbor benthos (Table 25). This polychaete is distributed throughout the harbor from King Industries to Sheffield Harbor. It is a sedentary species and is an important food source for bottom feeding finfish such as the winter flounder.

This baseline for *Nereis* can be used to monitor future changes in trace metal levels.

VII. Water Chemistry

The carrying capacity of coastal systems like Norwalk Harbor is controlled by climatic, oceanic and terrestrial factors that influence the condition of its waters. The chemistry of estuarine waters is complex because of the number of elements and compounds present and the multitude of ways in which they are involved with the biochemical processes of the diverse biota. The activities of man complicate the water chemistry through the addition of nutrients and other salts, trace metals, organic compounds and others.

The chemical and physical characteristics constitute the abiotic component of estuarine ecosystems. These chemical and physical parameters such as temperature, salinity, dissolved oxygen, pH, etc., exert a profound influence on biotic communities. When the range of one of these parameters is exceeded, the elimination of certain species can result. Pollution is a major cause of the disruption of normal chemical patterns in estuarine systems.

The federal government has established a set of water quality criteria for estuarine systems. These criteria specify concentrations of water constituents which, if not exceeded, are expected to support an aquatic ecosystem suitable for the higher uses of water. They provide an index to the sucess of local water management programs.

It is therefore essential that environment managers be provided with a comprehensive baseline of water chemistry data. Without this baseline, future changes in water chemistry and water quality cannot be detected.

Methods

Vertical profiles of temperatures, salinity, and turbidity were obtained using Yellow Springs Instruments meters. pH was determined with a digital pH meter. All other chemical parameters were determined with a Hach Chemical Model DR/EL2 Water Engineering Lab according to standard methods. Dissolved oxygen values were obtained using the Winkler Titration method.

All water chemistry values are summarized in Tables 5-22. Mean seasonal values for major harbor regions are summarized in Tables 19 and 21.

Temperature

Water temperature is one of the most significant factors controlling the health and distribution of marine organisms. Water temperature ranges are also a major force in determining the character of estuarine ecosystems by their influence upon the area of distribution of organisms and their metabolic and behavioral conditions including spawning, feeding, migration, and growth.

Variation in water temperature, whether natural or induced by activities of man, can have significant impacts upon marine organisms. Increased water temperatures accelerate the biodegradation of organic matter found in the water column and bottom sediments which increases demands upon the dissolved oxygen resources of the estuary. Then temperature-induced demands upon 0_2 resources are further aggravated by the reduced solubility of 0_2 in water with the increase of temperature. This may lead to total 0_2 depletion and obnoxious anaerobic conditions.

EPA standards (1973) limit artificially induced increases in temperature to not more than 1.5^{o}F in summer (June-August) or more than 4.0^{o}F during the rest of the year. It therefore becomes imperative to be able to differentiate between the naturally occurring fluctuations in water temperature and those caused by man's interaction with the natural system.

Surface and bottom water temperatures were highest in the inner harbor and lowest in the outer harbor. Mean surface water temperatures increased in the inner harbor from 15.3^{o}C in the spring to 25.1^{o}C in the

TABLE 19 . Seasonal Mean Values for Water Chemistry Parameters (Norwalk Harbor), Major Harbor Regions (Summer 1980).

Harbor Region: Parameter	Inner	Middle	Outer
Chlorine (mg/L)	0.04	0.04	0.05
Color (units)	19.9	20.8	16.8
Ammonia (mg/L)	2.1	2.05	2.0
Nitrate (mg/L)	0.55	0.47	0.5
Alkalinity (Total)	139.7	138.0	138.9
pH	8.1	8.4	8.25
Secchi Disk (feet)	4.2	5.8	7.3
Turbidity (NTU)	11.3	7.7	6.4
Phosphate (mg/L)	1.75	0.85	0.82
Salinity (‰)			
Surface	25.7	29.7	30.7
Bottom	28.3	29.8	29.5
Temperature (°C)			
Surface	25.1	24.5	23.2
Bottom	24.3	23.5	21.7
Oxygen (mg/L)	6.8	7.2	7.1

TABLE 21. Seasonal Mean Values for Water Chemistry Parameters (Norwalk Harbor), Major Harbor Regions (Spring 1980).

Harbor Region: Parameter	Inner	Middle	Outer
Chlorine (mg/L)	0.14	0.11	0.11
Color (units)	30.6	21.7	15.4
Ammonia (mg/L)	2.0	2.1	2.2
Nitrate (mg/L)	0.73	0.76	0.69
Alkalinity (Total)	128.8	115.0	132.5
pH	7.9	7.8	8.0
Secchi Disk (feet)	4.2	3.8	6.5
Turbidity (NTU)	6.9	6.5	3.9
Phosphate (mg/L)	1.83	2.02	1.65
Salinity (°/oo)			
Surface	15.2	24.5	27.5
Bottom	25.2	26.5	27.5
Temperature (°C)			
Surface	15.3	14.2	12.5
Bottom	14.2	12.7	9.8
Oxygen (mg/L)	10.0	10.1	9.7

summer while bottom temperatures went from 14.2°C to 24.3°C. Surface temperatures for the outer harbor during the same period went from 12.5°C to 23.2°C while bottom temperatures went from 9.8°C to 21.7°C.

Monthly mean surface water temperatures (Tables 6 and 7) went from 5°C at Station 5 in April to 26°C in August while bottom values increased from 4°C to 23°C. Surface water values declined to 19°C by the end of October.

Salinity

The annual cycle of salinity results from the annual cycle of stream flow of the rivers flowing into Long Island Sound and to a lesser extent any "spot conditions" caused by additions of freshwater by man. Salinity levels are found to be at their maximum usually at the end of winter. The large volumes of freshwater runoff which are discharged into the harbor system during the spring reduces salinity to its minimum by early summer.

The salinity of coastal waters reflects a complex mixture of dissolved salts, the most abundant of which is sodium chloride. Salinity determines or affects some of the most important physical and chemical characteristics of sea water. Salinity can undergo marked seasonal and diurnal variations in estuarine systems. It is therefore one of the most important factors limiting the distribution of estuarine organisms.

Surface and bottom salinity values increased from inner to outer harbor regions (Tables 19 and 21). Salinities were lowest during the spring and highest in the summer. Mean inner harbor surface salinities increased from 15.2% in spring to 25.7% in summer while bottom values went from 25.2 to 28.3%.

Outer harbor surface values increased from 27.5% in the spring to 30.7% during the summer. Surface values at Station 5 increased from 24.0% in April to 31% in September.

Dissolved Oxygen

Dissolved oxygen historically has been of major interest in water quality investigations. It generally has been considered as significant in the protection of aesthetic qualities as well as for the maintenance of marine life. Insufficient dissolved oxygen in the water column causes the anaerobic decomposition of organic matter. This decomposition causes the evolution of noxious gases such as hydrogen sulfide. Reduced levels of dissolved oxygen can cause mass die-offs of finfish and invertebrate species.

EPA standards suggest that dissolved oxygen levels be maintained at 6.0 ppm or higher. Lower 0_2 levels normally signify adverse effects from unnatural causes. The standard set recognizes, however, that some natural phenomena may cause 0_2 levels to fall below 4.0 ppm.

Mean Dissolved Oxygen values were highest in the spring and lowest during the summer. Oxygen values (3 feet depth) were almost constant throughout the harbor during the spring (Table 21) and most of the summer. This in marked contrast to past years when oxygen values were extremely low in the inner harbor.

Mean dissolved oxygen values declined from 10.0 mg/L in the inner harbor during the spring to 6.8 mg/L in the summer. This is still above the minimum value established by EPA. Outer harbor values declined from 9.7 mg/L during the spring to 7.1 in the summer.

Oxygen values at Station 5 (Table 16) ranged from 10.6 mg/L in April to a low of 6.3 in September. Oxygen values increased sharply during October to 12.2 mg/L.

Nutrients (Nitrates and Phosphates)

Phosphates are widely used in municipal and private water treatment systems and are commonly grouped into three types: orthophospate, condensed phosphate and organically bound phosphate. Nitrate represents the most highly oxidized phase in the nitrogen cycle. Nitrates and phosphates enter estuarine systems from agricultural run-off, water treatment and biological wastes and residues.

Certain amounts of nitrates and phosphates are essential for phytoplankton and algal growth but excessive levels can produce eutrophication or over fertilization. No EPA standards are available for indicating maximum acceptable levels for these nutrients.

Phosphate levels (mean) for the inner harbor were slightly higher during the spring (1.83 mg/L) than the summer (1.75 mg/L). The middle harbor region exhibited high phosphate levels in the spring (2.02 mg/L) and low values in the summer (0.85 mg/L). This can be attributed to dredging operations in that area during the spring months. Phosphate levels were again elevated in the outer harbor during the spring (1.65 mg/L) but declined to 0.82 mg/L in the summer.

Nitrate levels were consistently lower than phosphate and exhibited little seasonal or spatial variations (Tables 19 and 21).

Ammonia

Ammonia is one of the intermediates in the bacterial decomposition of nitrogen-containing compounds which eventually terminates at nitrate. Ammonia may reach the marine environment in sewage effluents and as a result of its use in industrial processes and in agriculture. Ammonia is therefore not a persistent substance and high concentrations therefore usually indicate domestic pollution.

The concentration of ammonia was fairly constant throughout the harbor (Tables 19 and 21) and exhibited little apparent seasonal variation.

Alkalinity and Acidity

Alkalinity refers to the capability of water to neutralize acids. The presence of carbonates, bicarbonates and hydroxides is the most common cause of alkalinity in coastal waters. Extremely high levels of alkalinity indicate the presence of a strongly alkaline industrial waste. Total alkalinity includes all carbonate, bicarbonate and hydroxide alkalinity.

Acidity is a quantitative expression of a water's capacity to neutralize a strong base to a designated pH. Acidity is caused by weak organic acides such as carbonic or tannic and by strong mineral acids.

Mean alkalinity values (Tables 19 and 21) were fairly constant throughout the harbor and exhibited little seasonal variation.

Chlorine

Chlorine has and continues to be the principal biocide in systems using marine waters for cooling purposes. Chlorine is also added to sewage plant effluents to destroy pathogenic bacteria. Chlorine has been shown to be highly toxic to phytoplankton and zooplankton species. Chlorine can be present as free available chlorine (Hypochlorous Acid and Hypochlorite ion) and combined available chlorine. Free available chlorine was examined during this study.

Mean free chlorine values were significantly higher during the spring than the summer for all harbor regions. Spring values ranged from 0.14 mg/L for the inner harbor to 0.14 mg/L for the middle and outer while mean summer values declined to 0.04 to 0.05 mg/L throughout the system.

pH

The pH of a water sample expresses its tendency to accept or donate hydrogen ions on a scale of 0 (very acidic) to 14 (very basic). Pure water at 25^{o}C is neutral and has a defined pH value of 7.

A major deviation from the normal pH indicates the intrusion of strongly acidic or alkaline industrial wastes.

Mean pH values (Tables 19 and 21) were lowest throughout the harbor during spring and slightly higher during summer. pH values were virtually constant throughout the harbor during spring ranging between 7.8 and 8.0. The middle harbor exhibited the greatest variation in pH values going from 7.8 in the spring to 8.4 in the summer.

Turbidity

Turbidity occurs in coastal waters as the result of suspended clay, silt, finely divided organic and inorganic matter, plankton and other microorganisms. Since coastal waters have a natural content of inorganic and organic matter, turbidity undergo considerable variation.

Turbidity was measured with a true nephelometer or turbidimeter at a depth of 3 feet and was also estimated by taking regular secchi disc readings. Mean turbidity values (NTU) (Tables 19 and 21) were highest in the inner harbor and lowest in the outer region. Turbidity values were highest during the summer months throughout the system. Mean inner harbor values were 11.3 NTU in the summer and only 6.9 NTU in the spring while outer harbor values during the same periods were 6.4 NTU and 3.9 NTU.

Secchi disc readings were also lowest in the inner harbor and highest in the outer except for the middle harbor during the spring. This low value (3.8) can again be attributed to dredging operations in that vicinity.

Color

Color in water may result from the presence of natural metallic ions (iron and Manganese), humus, plankton and industrial wastes. The color value of water is extremely pH dependent and invariably increases as the pH of the water is raised.

Apparent color includes not only the color due to substances in solution but also that due to suspended matter. Apparent color was measured during this study (1 color unit being equal to 1 mg/L platinum as chloroplatinate ion).

Mean color values (Tables 19 and 21) for the inner harbor were highest in the spring (30.6) and lowest in the summer (19.9). Middle harbor values showed little seasonal variation going from 21.7 in the spring to 20.8 in the summer. Outer harbor values were slightly higher in the summer (16.8) when compared to spring (15.4).

VIII. Potential Effects of Coal Transportation and Storage on the Norwalk Harbor Ecosystem

Coal Transportation

The increased need for barge shipments to the Manresa Island Plant could result in a degradation of water quality over Norwalk's prime shellfish grounds (Figure 3). The increased barge traffic would increase the possibility of accidental discharges of oil and diesel fuel, spillage of coal into the harbor and increased sediment resuspension (turbidity) from tugboat operations.

These effects would be most significant during the summer months when metabolism of organisms is highest and when spawning of commercially valuable shellfish species is taking place. Oyster and clam larvae are highly susceptible to changes in water chemistry and to even slight increases in the levels of toxic substances. A significant increase in larval mortality could cause an eventual reduction in the size of shellfish populations in future years.

Coal Storage

The major impacts to Norwalk Harbor from coal storage piles would result from surface-water runoff. This runoff would contain coal fines and and various concentrations of trace metals.

Shellfish

Metal levels in oysters and clams were found to be elevated which therefore resulted in their being designated as Class II shellfish. Class I is the best possible designation (lowest metal levels) and Class IV is the worst (highest metal levels). According to this system only Class IV shellfish would have metal levels in excess of Federal guidelines and would therefore be the only class to pose a potential health hazard.

The chronic input of trace metals into the harbor ecosystem from coal pile runoff could only result in increased levels of these toxic substances in the tissues of oysters and clams. This could, in future years, cause the shellfish to be elevated to Class III and possibly to Class IV.

Elevation of shellfish to Class IV status would cause severe restrictions in commercial and recreational harvesting. It would result in economic losses to the City of Norwalk and could pose a health problem to individuals that continue to harvest shellfish in defiance of the ban.

Sediments

The chronic input of trace metals from coal pile runoff would lead to increased concentrations in harbor sediments. Current metal levels have been shown to be elevated especially in the inner harbor.

Through the processes of bioconcentration, bioaccumulation, and biomagnification, these metals will be transferred to the benthos and ultimately to finfish.

Benthos

The chronic input of trace metals from coal pile runoff would lead to increased levels in the tissues of benthos invertebrates. This will ultimately result in increases in the tissues of finfish species which prey upon these organisms.

Deposit feeding invertebrates like *Nereis succinea* will have the highest levels of trace metals because they are in direct contact with the sediment and actually ingest sediment while feeding.

Finfish

Chronic input of trace metals from coal pile runoff would ultimately lead to increased levels in the tissues of finfish. This is especially important for resident species such as the winter flounder which spend most of their time within the harbor ecosystem.

Winter flounder were found to have elevated but still not high levels of trace metals within their musculature. These levels conform to all current Federal guidelines and therefore pose absolutely no health hazard.

Additional inputs of trace metals into the harbor could ultimately raise tissue concentrations to unhealthy levels.

Water Chemistry

1. Chlorine - No anticipated impact
2. Ammonia - No anticipated impact
3. Nitrates and Phosphates - No anticipated impact
4. Temperature - No anticipated impact
5. Salinity - No anticipated impact
6. Turbidity - Significant potential impact

Chronic runoff from coal storage piles would result in increases in both suspended and dissolved solids. These increased levels would be most important during the summer months when surface waters contain large numbers of shellfish and finfish larvae.

Increased turbidity in Norwalk Harbor would result in a reduction in light penetration with a subsequent decrease in photosynthesis. This could result in an overall reduction in the primary productivity of the system.

Chronic inputs of suspended solids would also increase the potential for the siltation of oyster beds in the outer harbor. MacKenzie (1976) found that siltation was the second most important cause of oyster seed mortality in Connecticut. Galtsoff (1964) also reported that many formerly productive oyster bottoms along the Atlantic Coast have been destroyed by a high rate of sedimentation. He also states that a thin deposit of loose sediment only 1-2mm thick is enough to make the surface of shells unsuitable for the attachment of oyster larvae.

Increased levels of suspended and dissolved solids would also increase the mortality of oyster and clam larvae.

7. pH - Significant potential impact

Chronic imputs of dissolved solids from coal pile runoff could change the normal harbor pH regieme. Changes in pH levels can cause severe physiological effects in organisms. These effects would again be most pronounced in the larval stages.

pH also affects the form and therefore the uptake of trace metals by organisms. pH changes can therefore affect the toxicity of trace metals to coastal species.

8. Oxygen - Minor potential impact

Chronic imputs of suspended and dissolved solids could lower oxygen levels by increasing oxygen demand and through the reduction in photosynthesis caused by decreased light penetration.

IX. Appendix A

Water Chemistry Values

(March, 1980 - October, 1980)

TABLE 5 . Water Chemistry Values for Norwalk Harbor (Station 1).

Parameter:	pH	Secchi Disk (feet)	Turbidity (NTU)	Phosphate (mg/L)	Salinity S	B	Temperature °C S	B
Date								
3/27/80	ND	5.0	6.0	0.98	6.5	22.0	1.8	0.0
4/1/80	ND	6.0	6.2	1.0	2.0	14.0	5.5	2.3
4/8/80	ND	6.0	6.8	1.3	2.1	19.5	6.0	3.8
4/22/80	8.0	5.5	3.9	1.3	6.5	28.5	14.0	9.5
5/6/80	8.0	4.5	5.5	1.5	6.0	28.0	16.5	12.0
5/27/80	8.2	4.0	6.2	3.2	20.5	27.0	20.5	18.0
6/4/80	7.3	3.0	6.0	4.2	14.0	24.0	21.0	20.5
6/12/80	7.8	3.0	6.4	3.0	18.0	25.0	18.0	15.0
6/24/80	7.5	2.0	5.8	4.0	27.5	25.0	21.0	22.0
6/30/80	ND	3.0	9.0	2.7	15.0	25.0	24.0	21.0
7/7/80	7.7	4.0	6.1	1.9	13.5	23.0	24.0	25.0
7/14/80	ND	2.5	9.0	1.95	24.0	27.0	26.5	25.0
7/23/80	ND	1.5	6.8	2.5	18.0	29.0	27.5	25.5
7/30/80	ND	5.0	9.3	3.0	24.5	28.5	26.5	25.0
8/6/80	ND	3.0	7.2	2.5	20.0	25.0	29.0	29.0
8/13/80	ND	2.0	9.3	3.0	26.5	24.5	27.0	25.0
8/26/80	ND	5.0	3.2	1.7	28.0	27.7	25.0	24.0
9/24/80	ND	4.0	2.4	1.9	29.3	28.0	23.0	23.0
10/8/80	7.5	5.5	4.0	0.85	29.0	29.8	18.0	18.0
10/22/80								

TABLE 5A . Water Chemistry Values for Norwalk Harbor (Station 1).

Parameter:	Chlorine (mg/L)	Color (units)	Ammonia (mg/L)	Nitrate (mg/L)	Acidity (Phenol.)	Alkalinity (Total)	Oxygen (mg/L)
Date							
3/27/80	0.08	45	1.4	0.75	ND	ND	ND
4/1/80	0.15	20	0.8	0.8	ND	ND	11.6
4/8/80	0.25	25	8.5	1.0	ND	ND	ND
4/22/80	0.1	25	1.5	1.0	ND	ND	10.5
5/6/80	0.15	25	1.8	0.5	ND	ND	10.9
5/27/80	0.1	25	1.95	0.5	ND	ND	9.2
6/4/80	0.15	60	2.5	0.5	ND	ND	8.0
6/12/80	0.075	35	1.8	0.2	ND	ND	9.2
6/24/80	0.15	50	2.0	0.5	0	0	10.2
6/30/80	0.15	25	1.75	1.0	0	120	6.6
7/7/80	0.15	25	1.7	0.5	0	125	9.1
7/14/80	0.15	25	1.45	0.5	0	130	11.0
7/23/80	0.025	15	2.8	0.5	0	300	5.3
7/30/80	0.002	25	11.4	0.8	0	120	4.8
8/6/80	0.02	25	1.2	0.55	0	70	ND
8/13/80	0.001	25	2.6	0.5	0	120	6.0
8/26/80	0.01	10	2.0	0.75	0	150	4.1
9/24/80	0.01	10	2.0	0.5	0	120	6.4
10/8/80	0.0	25	1.9	0.025	0	120	8.4
10/22/80	0.0	15	1.8	0.5	0	150	8.0

TABLE 6 . Monthly Mean Values for Water Chemistry Values, Station 1 .

Month: Parameter	April	May	June	July	August	September	October
Chlorine (mg/L)	0.16	0.12	0.13	0.08	0.01	0.01	0.0
Color (units)	23.3	25.0	42.5	22.5	20.0	10.0	20.0
Ammonia (mg/L)	3.6	1.87	2.01	1.9	1.9	2.0	1.85
Nitrate (mg/L)	0.93	0.5	0.55	0.57	0.6	0.5	0.26
Alkalinity (Total)	—	—	—	168.8	113.3	120.0	135.0
pH	—	8.1	7.5	7.7	—	—	7.4
Secchi Disk (feet)	5.8	4.3	2.8	3.3	3.3	4.0	5.0
Turbidity (NTU)	5.6	5.9	6.8	7.8	6.5	2.4	5.6
Phosphate (mg/L)	1.2	2.4	3.5	2.3	2.4	1.9	1.26
Salinity (‰) Surface	3.5	13.3	18.6	20.0	24.8	29.3	29.0
Bottom	20.7	27.5	24.8	26.7	25.7	28.0	28.9
Temperature (°C) Surface	8.5	18.5	21.0	26.1	27.0	23.0	16.8
Bottom	5.2	15.0	19.6	25.1	26.0	23.0	17.0
Oxygen (mg/L)	11.1	10.1	8.5	7.5	5.1	6.4	8.2

TABLE 7 . Water Chemistry Values for Norwalk Harbor (Station 2).

Parameter:	pH	Secchi Disk (feet)	Turbidity (NTU)	Phosphate (mg/L)	Salinity S	Salinity B	Temperature °C S	Temperature °C B
Date								
3/27/80	ND	6.0	5.0	0.92	6.5	24.0	1.5	0.5
4/1/80	ND	5.5	8.5	2.0	2.0	20.0	3.8	2.0
4/8/80	ND	6.0	6.0	0.95	6.5	22.0	5.8	3.8
4/22/80	8.0	5.5	6.5	1.6	7.5	25.0	13.0	10.0
5/6/80	8.1	5.0	5.0	1.7	6.5	28.0	15.5	12.0
5/27/80	8.3	4.5	9.2	1.75	18.0	27.0	20.0	18.5
6/4/80	7.5	3.0	21.0	1.95	11.5	24.0	22.0	19.5
6/12/80	7.9	3.5	6.4	1.4	12.0	25.0	18.0	15.0
6/24/80	8.2	2.5	6.6	1.6	15.0	28.0	24.0	21.5
6/30/80	ND	2.5	9.0	2.2	17.5	27.0	21.5	20.0
7/7/80	8.3	3.0	6.9	1.05	12.0	24.0	25.0	27.0
7/14/80	ND	2.5	5.9	3.0	26.5	29.0	24.5	23.0
7/23/80	ND	2.0	10.5	1.25	20.0	28.0	27.5	27.5
7/30/80	ND	5.0	7.5	1.65	24.5	28.5	27.5	25.0
8/6/80	ND	3.0	4.4	2.6	22.5	28.0	28.0	26.0
8/13/80	ND	3.0	8.6	1.65	24.0	30.0	27.5	24.5
8/26/80	ND	6.5	2.8	1.5	21.0	30.0	27.0	24.0
9/24/80	ND	5.0	3.8	1.9	25.0	29.0	24.0	22.5
10/8/80	7.6	6.0	8.0	1.15	25.0	30.0	20.0	17.5
10/22/80	7.3	1.0	7.2	1.68	21.0	27.5	17.0	16.0

TABLE 7A . Water Chemistry Values for Norwalk Harbor (Station 2).

Parameter:	Chlorine (mg/L)	Color (units)	Ammonia (mg/L)	Nitrate (mg/L)	Acidity (Phenol.)	Alkalinity (Total)	Oxygen (mg/L)
Date							
3/27/80	0.05	40	1.5	10.0	ND	ND	ND
4/1/80	0.3	20	0.7	0.5	ND	ND	12.7
4/8/80	0.1	25	1.8	0.05	ND	ND	ND
4/22/80	0.12	25	1.8	1.0	ND	ND	11.5
5/6/80	0.1	50	1.6	0.75	ND	ND	11.8
5/27/80	0.1	40	1.85	0.5	ND	ND	10.2
6/4/80	0.15	30	1.4	1.0	ND	ND	6.7
6/12/80	0.05	35	2.4	0.2	ND	ND	9.1
6/24/80	0.20	75	2.8	1.0	0.2	120	12.1
6/30/80	0.15	25	1.8	1.0	45	145	6.1
7/7/80	0.15	25	1.9	1.0	20	150	9.5
7/14/80	0.15	25	1.35	1.0	15	140	10.5
7/23/80	0.225	25	2.4	0.5	25	210	5.3
7/30/80	0.004	25	2.8	0.5	0	130	4.2
8/6/80	0.05	50	1.45	0.05	0	140	3.4
8/13/80	0.005	25	3.0	0.5	0	130	6.5
8/26/80	0.01	10	4.2	0.75	0	150	4.8
9/24/80	0.01	10	1.9	0.5	0	135	8.7
10/8/80	0.025	35	1.95	0.025	0	140	7.5
10/22/80	0.01	35	1.75	0.1	0	160	7.2

TABLE 8. Monthly Mean Values for Water Chemistry Values, Station 2.

Month: Parameter	April	May	June	July	August	September	October
Chlorine (mg/L)	0.17	0.1	0.14	0.08	0.02	0.01	0.02
Color (units)	23.3	45.0	41.25	25.0	28.33	10.0	35.0
Ammonia (mg/L)	1.43	1.725	2.10	2.11	2.88	1.9	1.85
Nitrate (mg/L)	0.52	0.63	1.07	0.75	0.43	0.5	0.06
Alkalinity (Total)	ND	ND	132.5	157.5	140.0	135.0	150.0
pH	8.0	7.97	7.87	8.3	ND	ND	7.45
Secchi Disk (feet)	5.6	4.75	2.88	3.13	4.17	5.0	3.5
Turbidity (NTU)	7.0	7.1	10.75	7.7	4.6	38.0	7.6
Phosphate (mg/L)	1.52	1.73	1.79	1.74	1.92	1.90	1.42
Salinity (‰) Surface	5.30	12.25	16.00	19.50	22.83	25.0	23.0
Bottom	22.33	27.5	26.0	27.38	29.33	29.0	28.75
Temperature (°C) Surface	7.53	17.75	21.38	26.13	27.5	24.0	18.5
Bottom	5.27	15.25	19.0	25.63	24.83	22.5	16.75
Oxygen (mg/L)	12.1	11.0	8.5	7.94	4.9	8.7	7.35

TABLE 9 . Water Chemistry Values for Norwalk Harbor (Station 3).

Parameter:	pH	Secchi Disk (feet)	Turbidity (NTU)	Phosphate (mg/L)	Salinity S	Salinity B	Temperature °C S	Temperature °C B
Date								
3/27/80	ND	5.0	2.8	0.87	21.0	24.0	0.5	0.0
4/1/80	ND	4.0	7.5	1.7	16.5	20.0	4.0	2.0
4/8/80	ND	3.0	5.8	0.7	6.0	22.5	5.0	4.0
4/22/80	8.1	5.0	6.2	1.5	25.0	29.0	11.5	10.0
5/6/80	8.1	4.0	6.8	1.2	23.5	25.0	15.0	12.0
5/27/80	8.2	4.0	9.1	1.5	25.5	26.0	18.0	16.0
6/4/80	7.5	3.0	7.8	2.2	26.5	26.5	18.0	18.0
6/12/80	7.8	ND	5.3	1.2	26.5	26.0	17.0	15.0
6/24/80	7.7	3.0	2.7	2.4	28.0	28.0	22.0	19.0
6/30/80	ND	3.5	4.5	1.05	24.5	27.5	26.0	20.0
7/7/80	8.3	1.5	12.0	0.9	26.0	26.0	22.0	22.0
7/14/80	ND	3.0	5.1	1.5	31.0	30.0	24.0	22.0
7/23/80	ND	3.0	3.5	1.1	30.0	30.5	25.0	26.0
7/30/80	ND	4.0	6.0	1.0	28.5	30.0	27.0	23.5
8/6/80	ND	4.0	4.3	1.4	30.0	29.5	27.0	25.0
8/13/80	ND	5.0	7.5	1.0	30.0	29.0	26.0	24.0
8/26/80	ND	9.0	2.4	1.1	30.5	30.0	25.0	24.0
9/24/80	ND	5.0	2.2	1.4	31.0	29.5	21.5	22.0
10/8/80	7.8	7.0	5.4	0.75	30.9	30.5	17.8	17.0
10/22/80	7.7	4.0	6.8	0.87	30.0	30.0	15.0	15.8

TABLE 9A . Water Chemistry Values for Norwalk Harbor (Station 3).

Parameter:	Chlorine (mg/L)	Color (units)	Ammonia (mg/L)	Nitrate (mg/L)	Acidity (Phenol.)	Alkalinity (Total)	Oxygen (mg/L)
Date							
3/27/80	0.08	25	1.0	1.0	ND	ND	ND
4/1/80	0.12	15	1.4	0.9	ND	ND	10.7
4/8/80	0.15	25	1.75	1.0	ND	ND	ND
4/22/80	0.11	25	1.8	0.8	ND	ND	10.8
5/6/80	0.15	25	1.8	0.5	ND	ND	11.2
5/27/80	0.1	25	1.85	0.75	ND	ND	9.1
6/4/80	0.1	30	2.1	0.5	ND	ND	7.0
6/12/80	0.075	25	2.1	0.5	ND	ND	7.7
6/24/80	0.15	25	2.2	1.2	0.2	120	10.8
6/30/80	0.15	25	1.75	1.0	30	130	7.4
7/7/80	0.12	25	2.0	0.75	80	150	8.9
7/14/80	0.1	25	1.25	0.5	15	150	9.7
7/23/80	0.075	35	2.5	0.5	18	280	9.5
7/30/80	0.004	15	1.85	0.5	0	140	6.1
8/6/80	0.02	25	1.6	0.025	0	130	ND
8/13/80	0.005	15	1.85	0.5	0	140	6.8
8/26/80	0.01	10	3.0	0.5	0	130	6.3
9/24/80	0.01	0	2.2	0.5	0	110	6.0
10/8/80	0.0	20	2.0	0.025	0	110	11.1
10/22/80	0.01	15	1.8	0.75	0	170	11.6

TABLE 10. Monthly Mean Values for Water Chemistry Values, Station 3.

Month: Parameter	April	May	June	July	August	September	October
Chlorine (mg/L)	0.12	0.15	0.12	0.10	0.01	0.01	0.01
Color (units)	23	25	26	25	17	0	18
Ammonia (mg/L)	1.5	1.8	2.0	1.9	2.2	2.2	1.9
Nitrate (mg/L)	0.9	0.6	0.8	0.6	0.3	0.5	0.4
Alkalinity (Total)	ND	ND	125.0	180.0	133.0	110.0	140.0
pH	8.1	8.2	7.7	8.3	ND	ND	7.8
Secchi Disk (feet)	4.0	4.0	3.0	3.0	6.0	5.0	6.0
Turbidity (NTU)	5.6	8.0	5.1	7.9	4.7	22.0	6.1
Phosphate (mg/L)	1.2	1.4	1.7	1.1	1.2	1.4	0.8
Salinity (°/oo)							
Surface	17.1	24.5	26.4	29.0	30.0	31.0	30.5
Bottom	24.0	26.0	27.0	29.0	29.5	29.5	30.5
Temperature (°C)							
Surface	5.3	17.0	21.0	25.0	26.0	21.5	16.0
Bottom	5.3	14.0	18.0	23.0	24.5	22.0	16.0
Oxygen (mg/L)	10.8	10.0	8.2	8.6	6.5	6.0	11.5

TABLE 11 . Water Chemistry Values for Norwalk Harbor (Station 4).

Parameter:	pH	Secchi Disk (feet)	Turbidity (NTU)	Phosphate (mg/L)	Salinity S	Salinity B	Temperature °C S	Temperature °C B
Date								
3/27/80	ND	6.0	4.2	0.8	16.0	23.0	2.0	0.0
4/1/80	ND	4.5	6.3	1.7	5.5	21.0	4.5	2.0
4/8/80	—	—	—	—	—	—	—	—
4/22/80	8.1	3.5	6.8	1.6	27.0	28.0	11.5	11.0
5/6/80	8.1	3.5	8.1	2.0	23.5	27.0	14.5	12.5
5/27/80	8.2	3.0	8.5	1.5	27.0	28.0	18.0	16.5
6/4/80	7.5	2.5	5.2	1.3	26.0	26.0	18.0	18.0
6/12/80	7.9	ND	4.8	0.75	29.0	28.5	17.0	15.0
6/24/80	7.6	3.5	3.2	1.1	31.0	28.5	22.0	19.0
6/30/80	ND	3.5	3.5	1.8	28.0	28.0	21.0	20.0
7/7/80	8.4	4.0	10.0	0.8	27.0	27.0	21.0	21.0
7/14/80	ND	3.0	4.8	1.1	30.5	30.0	24.0	22.0
7/23/80	ND	2.5	5.8	0.95	29.0	29.0	25.5	27.0
7/30/80	ND	6.0	6.6	0.9	29.5	30.0	25.0	23.5
8/6/80	ND	5.0	8.0	1.5	28.0	29.0	27.0	26.0
8/13/80	ND	5.0	4.5	0.9	30.0	31.0	26.0	24.0
8/26/80	ND	9.0	2.3	0.65	30.0	31.0	25.0	23.8
9/24/80	ND	6.5	2.4	4.2	29.5	30.0	25.0	23.0
10/8/80	7.8	8.0	3.3	0.85	31.0	31.5	17.0	17.0
10/22/80	7.7	5.0	6.4	1.98	31.5	30.0	14.0	15.5

TABLE 11A. Water Chemistry Values for Norwalk Harbor (Station 4).

Parameter:	Chlorine (mg/L)	Color (units)	Ammonia (mg/L)	Nitrate (mg/L)	Acidity (Phenol.)	Alkalinity (Total)	Oxygen (mg/L)
Date							
3/27/80	0.1	25	1.9	0.75	ND	ND	ND
4/1/80	0.08	10	1.7	0.5	ND	ND	11.2
4/8/80	—	—	—	—	—	—	—
4/22/80	0.1	10	1.9	1.0	ND	ND	10.8
5/6/80	0.12	30	1.95	1.5	ND	ND	11.0
5/27/80	0.1	25	1.9	0.75	ND	ND	9.6
6/4/80	0.12	25	2.0	0.5	ND	ND	7.9
6/12/80	0.075	15	2.3	0.5	ND	ND	8.8
6/24/80	0.15	25	2.2	1.0	0.1	110	11.3
6/30/80	0.15	25	1.85	1.0	80	110	7.6
7/7/80	0.1	25	2.0	1.0	30	140	9.1
7/14/80	0.12	25	1.35	0.5	16	150	8.9
7/23/80	0.025	25	3.0	0.5	16	250	8.3
7/30/80	0.002	15	2.5	0.9	0	140	4.8
8/6/80	0.02	25	1.5	0.025	0	130	8.4
8/13/80	0.005	15	2.1	0.5	0	130	6.8
8/26/80	0.05	10	2.2	0.5	0	140	6.8
9/24/80	0.01	0	1.85	0.5	0	120	6.5
10/8/80	0.0	25	1.95	0.025	0	120	10.8
10/22/80	0.01	25	1.8	0.5	0	160	10.8

TABLE 12 . Monthly Mean Values for Water Chemistry Values, Station 4 .

Month: Parameter	April	May	June	July	August	September	October
Chlorine (mg/L)	0.09	0.11	0.1	0.1	0.03	0.01	0.01
Color (units)	10	28	24	24	17	0	25
Ammonia (mg/L)	1.8	2.0	2.1	2.2	1.9	1.9	1.9
Nitrate (mg/L)	0.75	1.1	0.8	0.7	0.3	0.5	0.3
Alkalinity (Total)	ND	ND	110	170	135	120	150
pH	8.1	8.15	5.67	8.4	ND	ND	7.75
Secchi Disk (feet)	4.0	3.25	3.17	3.75	6.33	6.5	6.5
Turbidity (NTU)	6.55	8.3	4.18	6.8	4.93	24.0	4.85
Phosphate (mg/L)	1.65	1.75	1.2	0.9	1.0	4.2	1.4
Salinity (°/oo)							
Surface	16.25	25.25	28.25	29.0	29.33	29.5	31.25
Bottom	24.5	27.5	27.75	29.0	29.67	30.0	30.75
Temperature (°C)							
Surface	8.0	16.25	19.5	23.88	26.0	25.0	15.5
Bottom	6.5	14.5	18.0	23.25	24.6	23.0	16.25
Oxygen (mg/L)	11.0	10.3	8.9	7.7	6.8	6.5	10.8

TABLE 13 . Water Chemistry Values for Norwalk Harbor (Station 5).

Parameter:	pH	Secchi Disk (feet)	Turbidity (NTU)	Phosphate (mg/L)	Salinity S	Salinity B	Temperature °C S	Temperature °C B
Date								
3/27/80	ND	7.5	3.7	0.52	22.0	20.0	2.5	1.8
4/1/80	ND	4.0	5.5	0.9	15.0	22.0	3.8	1.5
4/8/80	—	—	—	—	—	—	—	—
4/22/80	8.6	4.5	6.5	3.6	27.5	27.0	12.0	9.0
5/6/80	7.9	2.8	8.3	1.5	28.0	28.0	12.5	12.0
5/27/80	8.2	3.5	7.2	4.0	26.5	28.5	18.0	15.5
6/4/80	7.7	3.0	18.0	3.2	26.0	25.5	19.0	19.0
6/12/80	7.9	ND	5.6	2.7	26.0	27.0	19.0	16.0
6/24/80	8.0	4.3	3.0	4.0	31.0	30.0	21.5	19.0
6/30/80	ND	4.0	5.0	1.7	29.0	29.0	20.0	20.0
7/7/80	8.4	5.0	7.0	0.8	30.5	30.0	22.0	22.5
7/14/80	ND	4.5	3.5	0.8	31.0	30.5	23.0	20.5
7/23/80	ND	2.0	4.2	0.65	30.0	30.5	25.0	25.0
7/30/80	ND	6.0	9.2	1.2	30.0	30.0	24.0	23.5
8/6/80	ND	5.0	4.6	1.3	29.0	29.5	26.5	25.0
8/13/80	ND	8.0	3.7	1.3	30.0	31.0	26.0	24.0
8/26/80	ND	10.0	2.3	0.8	30.0	30.0	24.5	25.0
9/24/80	ND	6.0	2.0	0.9	30.0	30.0	22.0	22.0
10/8/80	7.9	9.5	2.8	0.6	31.0	31.0	17.5	17.0
10/22/80	7.8	6.5	6.8	1.1	29.5	30.0	16.0	15.5

TABLE 13A. Water Chemistry Values for Norwalk Harbor (Station 5).

Parameter:	Chlorine (mg/L)	Color (units)	Ammonia (mg/L)	Nitrate (mg/L)	Acidity (Phenol.)	Alkalinity (Total)	Oxygen (mg/L)
Date							
3/27/80	0.07	15	2.5	0.8	ND	ND	ND
4/1/80	0.005	15	1.6	0.8	ND	ND	10.7
4/8/80	—	—	—	—	—	—	—
4/22/80	0.12	25	3.50	0.8	ND	ND	10.9
5/6/80	0.15	25	1.95	0.5	ND	ND	11.6
5/27/80	0.15	35	2.0	0.5	ND	ND	9.8
6/4/80	0.15	25	1.5	0.8	ND	ND	8.0
6/12/80	0.15	15	1.7	0.5	ND	ND	8.5
6/24/80	0.15	10	2.4	0.5	20	110	9.8
6/30/80	0.15	25	1.8	0.75	30	130	7.5
7/7/80	0.1	25	2.5	0.75	50	150	9.0
7/14/80	0.11	25	1.4	0.5	15	130	10.1
7/23/80	0.025	45	2.8	0.5	18	240	8.5
7/30/80	0.004	10	2.6	0.5	0	130	4.8
8/6/80	0.01	85	1.75	0.25	0	125	8.1
8/13/80	0.005	10	2.0	0.3	0	120	6.6
8/26/80	0.02	10	2.4	0.5	0	125	7.4
9/24/80	0.01	0	1.85	0.25	0	115	6.7
10/8/80	0.0	20	2.0	0.01	0	128	11.9
10/22/80	0.025	20	1.75	0.25	0	165	11.9

TABLE 14 . Monthly Mean Values for Water Chemistry Values, Station 5 .

Month: Parameter	April	May	June	July	August	September	October
Chlorine (mg/L)	0.07	0.15	0.15	0.06	0.01	0.01	0.03
Color (units)	18	30	19	26	15	0	20
Ammonia (mg/L)	2.5	2.0	1.9	2.3	2.1	1.9	1.9
Nitrate (mg/L)	0.8	0.5	0.6	0.6	0.4	0.3	0.1
Alkalinity (Total)	ND	ND	120	163	123	115	147
pH	8.6	8.1	7.9	8.4	ND	ND	7.9
Secchi Disk (feet)	5.3	3.2	3.8	4.4	8.0	6.0	8.0
Turbidity (NTU)	5.2	7.8	7.9	6.0	3.5	2.0	4.8
Phosphate (mg/L)	1.7	2.8	2.9	0.9	1.1	0.9	0.9
Salinity (°/oo) Surface	22.0	27.0	28.0	30.0	30.0	30.0	30.0
Bottom	23.0	28.0	28.0	30.0	30.0	30.0	30.0
Temperature (°C) Surface	6.1	15.3	20.0	24.0	26.0	22.0	17.0
Bottom	4.1	13.8	19.0	23.0	25.0	22.0	16.0
Oxygen (mg/L)	10.8	10.7	8.5	8.1	7.4	6.7	11.9

TABLE 15. Water Chemistry Values for Norwalk Harbor (Station 6).

Parameter:	pH	Secchi Disk (feet)	Turbidity (NTU)	Phosphate (mg/L)	Salinity S	Salinity B	Temperature °C S	Temperature °C B
Date								
3/27/80	ND	7.0	4.6	0.39	23.5	24.0	1.8	1.0
4/1/80	ND	5.0	5.6	1.0	21.0	23.0	3.0	2.0
4/8/80	—	—	—	—	—	—	—	—
4/22/80	8.6	6.0	7.0	1.9	27.0	27.0	11.5	8.0
5/6/80	7.9	6.0	2.5	1.9	28.0	29.0	12.0	10.0
5/27/80	8.1	5.5	3.9	1.5	28.0	28.5	16.0	14.0
6/4/80	7.6	5.5	5.1	1.5	28.0	25.5	17.0	15.5
6/12/80	7.9	ND	5.4	1.6	28.0	29.0	15.9	14.0
6/24/80	7.8	7.0	3.2	1.7	30.0	29.0	20.5	17.0
6/30/80	ND	5.5	4.5	1.4	29.0	29.0	20.0	19.0
7/7/80	8.3	7.0	4.0	0.6	32.5	24.0	23.5	17.0
7/14/80	ND	5.5	3.9	0.65	30.5	30.0	22.0	21.0
7/23/80	ND	4.0	8.8	0.9	31.5	31.0	24.5	20.5
7/30/80	ND	9.0	7.9	1.0	30.0	30.1	23.0	22.5
8/6/80	ND	7.0	4.1	0.7	31.0	30.5	28.0	22.0
8/13/80	ND	7.0	4.2	0.65	30.5	30.5	25.0	23.0
8/26/80	ND	10.0	2.0	0.75	29.5	30.0	25.0	23.5
9/24/80	ND	6.5	18.0	0.9	30.5	30.5	21.5	22.0
10/8/80	7.9	10.0	3.0	0.65	29.0	30.8	21.0	18.5
10/22/80	7.9	7.0	4.4	0.78	30.2	31.0	16.0	17.0

TABLE 15A. Water Chemistry Values for Norwalk Harbor (Station 6).

Parameter:	Chlorine (mg/L)	Color (units)	Ammonia (mg/L)	Nitrate (mg/L)	Acidity (Phenol.)	Alkalinity (Total)	Oxygen (mg/L)
Date							
3/27/80	0.1	15	3.0	0.05	ND	ND	10.6
4/1/80	0.005	15	1.8	0.8	ND	ND	ND
4/8/80	—	—	—	—	—	—	—
4/22/80	0.15	25	2.30	0.9	ND	ND	11.0
5/6/80	0.15	10	2.25	0.75	ND	ND	9.6
5/27/80	0.15	15	3.5	0.5	ND	ND	8.8
6/4/80	0.15	25	1.9	0.5	ND	ND	6.9
6/12/80	0.1	15	1.5	0.75	ND	ND	8.0
6/24/80	0.15	10	1.9	10	10	120	9.8
6/30/80	0.10	25	1.95	0.85	50	150	7.5
7/7/80	0.12	15	2.5	1.0	40	120	7.9
7/14/80	0.1	25	1.35	0.5	17	150	8.9
7/23/80	0.05	25	2.5	0.35	19	260	6.9
7/30/80	0.004	15	1.95	0.6	0	120	5.5
8/6/80	0.01	25	1.75	0.025	0	150	9.6
8/13/80	0.005	15	1.95	0.5	0	120	5.2
8/26/80	0.02	10	1.9	0.5	0	125	7.0
9/24/80	0.0	0	1.9	0.75	0	130	6.3
10/8/80	0.0	25	2.0	0.025	0	115	11.7
10/22/80	0.01	15	2.0	0.35	0	165	12.6

TABLE 16. Monthly Mean Values for Water Chemistry Values, Station 6.

Month: Parameter	April	May	June	July	August	September	October
Chlorine (mg/L)	0.09	0.15	0.13	0.07	0.01	0.0	0.01
Color (units)	18	13	19	20	17	0	20
Ammonia (mg/L)	2.4	2.9	1.8	2.1	1.9	1.9	2.0
Nitrate (mg/L)	0.6	0.6	0.8	0.6	0.3	0.8	0.2
Alkalinity (Total)	ND	ND	135	163	130	130	140
pH	8.6	8.0	7.7	8.3	ND	ND	7.9
Secchi Disk (feet)	6.0	6.0	6.0	6.0	8.0	6.5	8.0
Turbidity (NTU)	5.7	3.2	4.6	6.2	3.4	18.0	3.7
Phosphate (mg/L)	1.1	1.7	1.6	0.8	0.7	0.9	0.8
Salinity (‰) Surface	24.0	28.0	29.0	31.0	30.0	31.0	30.0
Bottom	25.0	29.0	28.0	29.0	30.0	31.0	31.0
Temperature (°C) Surface	5.0	13.0	18.0	23.0	26.0	22.0	19.0
Bottom	4.0	8.0	16.0	20.0	23.0	22.0	18.0
Oxygen (mg/L)	10.6	10.3	8.1	7.3	7.3	6.3	12.2

TABLE 17 . Water Chemistry Values for Norwalk Harbor (Station 7).

Parameter:	pH	Secchi Disk (feet)	Turbidity (NTU)	Phosphate (mg/L)	Salinity S	Salinity B	Temperature °C S	Temperature °C B
Date								
3/27/80	—	—	—	—	—	—	—	—
4/1/80	ND	5.5	4.2	1.1	22.0	23.5	3.0	1.5
4/8/80	—	—	—	—	—	—	—	—
4/22/80	8.0	8.0	2.2	3.8	30.0	28.0	9.0	7.0
5/6/80	7.9	6.0	2.8	2.0	28.5	29.0	12.0	10.0
5/27/80	8.1	5.5	3.3	1.3	28.5	28.0	15.5	13.0
6/4/80	7.6	6.0	4.3	1.1	29.0	26.5	16.5	13.0
6/12/80	7.2	ND	4.5	0.95	26.0	27.0	19.0	16.0
6/24/80	7.7	9.0	1.2	1.3	31.0	29.0	20.0	18.0
6/30/80	ND	8.0	4.0	1.5	28.5	29.0	19.5	18.0
7/7/80	8.2	9.0	3.4	0.5	30.0	28.5	18.0	17.0
7/14/80	ND	5.0	3.6	0.65	30.0	30.5	21.0	21.0
7/23/80	ND	5.0	4.8	0.75	30.0	31.0	22.5	20.0
7/30/80	ND	12.0	4.8	0.7	30.8	31.0	23.5	21.5
8/6/80	ND	5.0	4.3	0.6	30.0	25.3	25.0	23.0
8/13/80	ND	10.0	4.0	1.0	30.0	30.0	24.0	22.0
8/26/80	ND	9.0	2.0	0.65	30.0	30.5	24.0	22.0
9/24/80	ND	7.0	2.8	1.0	31.0	30.5	21.5	21.5
10/8/80	8.0	12.0	3.1	0.65	26.9	28.5	21.5	20.0
10/22/80	7.8	6.0	5.2	1.2	30.0	31.0	16.5	17.0

TABLE 17A. Water Chemistry Values for Norwalk Harbor (Station 7).

Parameter:	Chlorine (mg/L)	Color (units)	Ammonia (mg/L)	Nitrate (mg/L)	Acidity (Phenol.)	Alkalinity (Total)	Oxygen (mg/L)
Date							
3/27/80	—	—	—	—	—	—	—
4/1/80	0.0075	15	1.65	0.8	ND	ND	10.8
4/8/80	—	—	—	—	—	—	—
4/22/80	0.12	10	2.0	0.7	ND	ND	11.3
5/6/80	0.13	10	2.1	1.0	ND	ND	10.0
5/27/80	0.1	10	3.0	0.1	ND	ND	9.9
6/4/80	0.12	15	1.7	0.5	ND	ND	6.4
6/12/80	0.1	25	1.65	0.5	ND	ND	7.2
6/24/80	0.15	10	1.7	0.75	10	120	10.3
6/30/80	0.15	25	1.75	0.75	70	140	7.7
7/7/80	0.12	15	2.0	0.75	30	120	7.3
7/14/80	0.5	25	1.45	0.5	20	140	7.6
7/23/80	0.05	10	2.5	0.5	25	270	7.5
7/30/80	0.004	10	2.4	0.5	0	110	5.9
8/6/80	0.01	25	1.6	0.025	0	145	11.2
8/13/80	0.005	10	2.8	0.5	0	110	4.2
8/26/80	0.02	10	2.0	0.5	0	120	7.6
9/24/80	0.01	0	1.75	0.5	0	125	6.4
10/8/80	0.05	20	2.0	0.025	0	110	13.0
10/22/80	0.01	10	1.9	0.25	0	170	13.1

TABLE 18. Monthly Mean Values for Water Chemistry Values, Station 7.

Month: Parameter	April	May	June	July	August	September	October
Chlorine (mg/L)	0.06	0.12	0.13	0.17	0.01	0.01	0.03
Color (units)	13	10	19	15	15	0	15
Ammonia (mg/L)	1.8	2.6	1.7	2.1	2.1	1.8	2.0
Nitrate (mg/L)	0.8	0.6	0.6	0.6	0.3	0.5	0.1
Alkalinity (Total)	ND	ND	130	160	125	125	140
pH	8.0	8.0	7.5	8.2	ND	ND	8.0
Secchi Disk (feet)	7.0	6.0	8.0	8.0	8.0	7.0	9.0
Turbidity (NTU)	3.2	3.1	3.5	4.2	3.4	2.8	4.0
Phosphate (mg/L)	2.5	1.7	1.2	0.7	0.8	1.0	0.9
Salinity (‰) Surface	26.0	28.5	29.0	30.0	30.0	31.0	29.0
Bottom	26.0	29.0	28.0	30.0	27.0	30.0	30.0
Temperature (°C) Surface	6.0	14.0	19.0	21.0	24.0	22.0	19.0
Bottom	3.0	12.0	16.0	20.0	22.0	22.0	19.0
Oxygen (mg/L)	11.1	10.0	7.9	7.1	7.9	6.4	13.0

TABLE 20. Seasonal Mean Values for Water Chemistry Parameters, Norwalk Harbor (Summer 1980).

Station: Parameter	1	2	3	4	5	6	7
Chlorine (mg/L)	0.03	0.04	2.04	0.05	0.03	0.04	0.06
Color (units)	17.5	21.1	21.0	21.0	20.5	18.5	15.0
Ammonia (mg/L)	1.9	2.3	2.1	2.0	2.1	2.0	2.0
Nitrate (mg/L)	0.56	0.56	0.5	0.5	0.43	0.6	0.4
Alkalinity (Total)	134	144	141	142	134	141.1	136.7
pH	7.7	8.3	8.3	8.4	8.4	8.3	8.2
Secchi Disk (feet)	3.5	4.1	5.0	5.5	6.1	6.8	7.7
Turbidity (NTU)	5.6	16.8	11.5	11.9	3.8	9.2	3.5
Phosphate (mg/L)	2.2	1.85	1.2	0.7	1.0	0.8	0.83
Salinity (°/oo)							
Surface	24.7	22.4	30.0	29.3	30.0	31.0	30.3
Bottom	26.9	28.6	29.5	29.6	30.0	30.0	29.0
Temperature (°C)							
Surface	25.4	25.9	24.0	25.0	24.0	24.0	22.3
Bottom	25.7	24.3	23.0	23.6	23.3	22.0	21.3
Oxygen (mg/L)	6.3	7.2	7.0	7.0	7.4	7.0	7.1

TABLE 22. Seasonal Mean Values for Water Chemistry Parameters, Norwalk Harbor (Spring 1980).

Station:	1	2	3	4	5	6	7
Parameter							
Chlorine (mg/L)	0.14	0.14	0.14	0.10	0.12	0.12	0.10
Color (units)	30.2	36.5	25	21	22.3	16.7	14
Ammonia (mg/L)	2.5	1.75	1.8	2.0	2.1	2.4	2.0
Nitrate (mg/L)	0.66	0.74	0.8	0.88	0.63	0.7	0.67
Alkalinity (Total)	—	132.5	125	110	120	135	130
pH	7.8	7.9	8.0	7.3	8.2	8.1	7.8
Secchi Disk (feet)	4.3	4.4	4.0	3.5	4.1	6.0	7.0
Turbidity (NTU)	6.1	8.3	6.2	5.0	7.0	4.5	3.3
Phosphate (mg/L)	2.4	1.68	1.4	1.53	2.5	1.5	1.8
Salinity (°/oo)							
Surface	11.8	11.2	22.7	23.3	25.6	27.0	27.8
Bottom	24.3	25.3	26.0	26.6	26.3	27.3	27.7
Temperature (°C)							
Surface	16.0	15.6	14.4	14.6	13.8	12.0	13.0
Bottom	13.3	13.2	16.0	13.0	12.3	9.3	10.3
Oxygen (mg/L)	9.9	10.5	9.5	10.1	10.0	9.7	9.7

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