HYDRAULIC AND SEDIMENT CHARACTERISTICS AT THE NORTH CHANNEL BRIDGE, JAMAICA BAY, NEW YORK

By Ward W. Staubitz and Stephen W. Wolcott

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CONVERSION FACTORS AND ABBREVIATIONS

The following factors may be used to convert metric (International System) units of measurement used in this report to inch-pound units of measurement.

Multiply metric unit	by	To obtain inch-pound unit
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
square kilometer (km^2)	0.3861	square mile (mi^2)
cubic meter (m^3)	35.31	cubic foot (ft^3)
kilogram (kg)	2.205	pound (lb)
liter (L)	0.2642	gallon (gal)
degree Celsius (°C)	(1.8 x °C) + 32	degree Fahrenheit (°F)

Other abbreviations used in this report include:

cm, centimeter	g, gram
μ, micrometer	mg, milligram
m^2, square meters	mL, milliliter
cm^3, cubic centimeters	μg/L, microgram per liter
m/s, meters per second	mg/L, milligram per liter
m^3/s, cubic meters per second	mg/m^3, milligram per cubic meter
g/m^3, gram per cubic meter	μg/g, microgram per gram
mg/g, milligram per gram	μg/kg, microgram per kilogram
kg/d, kilogram per day	μS, microsiemens
oz, ounce	ft/s, feet per second
Mgal/d, million gallons per day	ft^3/s, cubic feet per second
ft^2, square feet	yd^3, cubic yards
ft^3, cubic feet	min, minute
mg/ft^3, milligram per cubic foot	h, hour

ERRATA

Page 6- second paragraph, line 8 should read "4-22L."

Page 7- first paragraph, last line should be "bridge."

Page 23- last paragraph, end of last line should read "procedure, and that the"

Page 37- second paragraph, second line should read "bacteria will follow"

Hydraulic and Sediment Characteristics at the North Channel Bridge, Jamaica Bay, New York

By Ward W. Staubitz and Stephen W. Wolcott

ABSTRACT

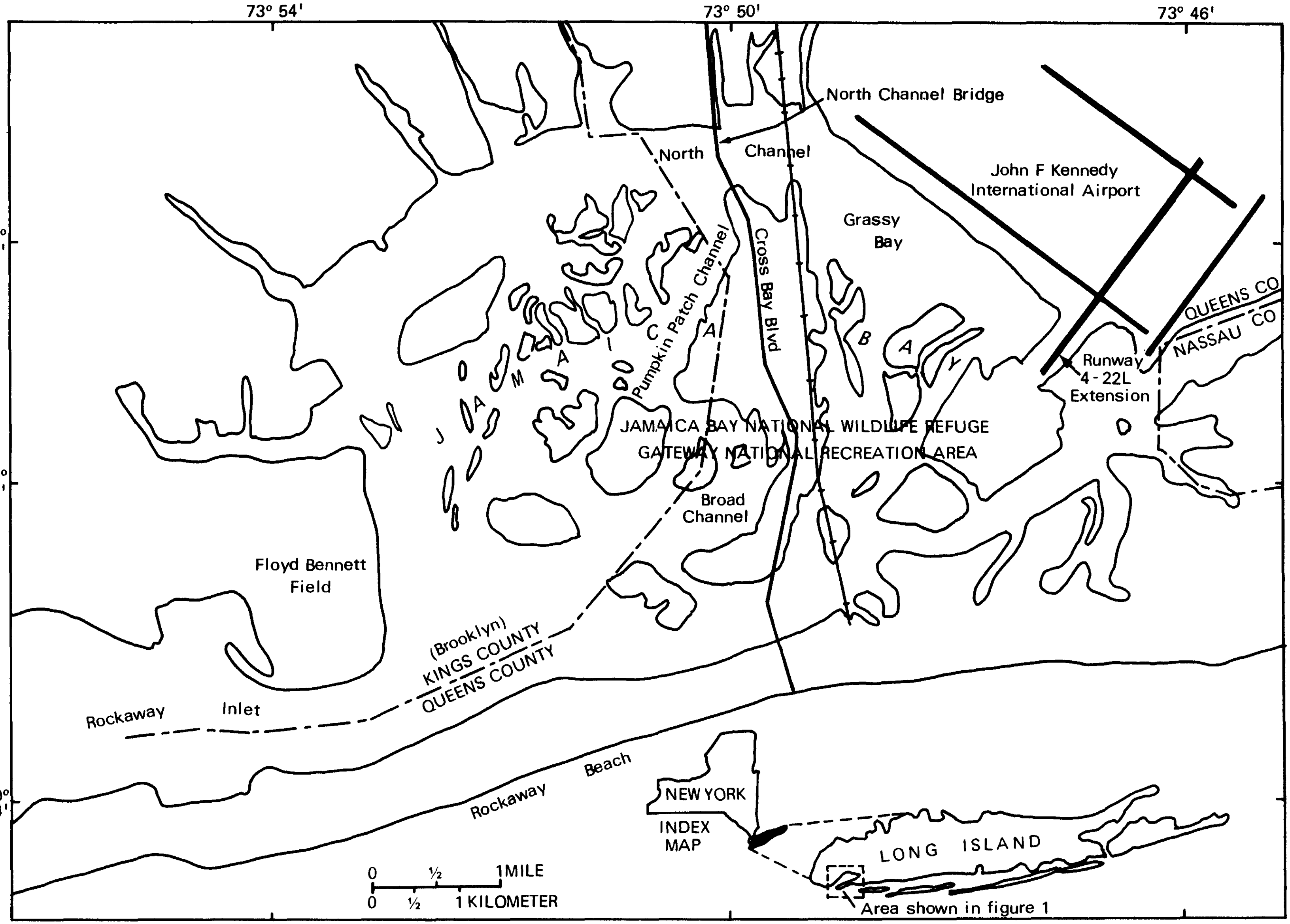
Data were collected during the spring of 1984 in the vicinity of North Channel bridge in Jamaica Bay to define the hydraulic regime and the physical characteristics and chemical quality of bottom sediments. The data were used in a semiquantitative analysis to predict the effects of bridge replacement on flow patterns, chemical quality of bay water, and distribution of bottom sediments within Jamaica Bay. The bottom configuration at the bridge site was delineated, and continuous tidal stage and tidal velocity data were collected for about 1 month. In addition, eight bottom-sediment samples were collected near the bridge and analyzed for particle size, settling velocity, biochemical oxygen demand, concentration of selected metals and organic compounds, and exchange of metals and nutrients to the water column.

Jamaica Bay is roughly circular with scattered landmasses in its center; the circulation patterns that form during tidal cycles can be evaluated from fluxes measured at the bridge. Results of the hydraulic analysis show that the present rate and direction of water movement at the bridge vary, but a net eastward flux of about 0.67×10^8 cubic feet occurs during each tidal cycle. The proposed bridge should have no measurable effect on the net water-volume transport at the bridge cross section. Scouring of bottom sediment beneath the proposed bridge is expected to be less than beneath the present one because fewer pilings will be used. The sediment data indicate that bottom sediments are relatively unpolluted in the bridge vicinity and that sand- and silt-sized aggregated particles predominate. About 75 percent of the resuspended bottom sediment will settle within 610 ft of the new bridge during an average ebb tide. A simple analysis of sediment transport and deposition indicates that the depth of sedimentation resulting from bridge replacement is not likely to exceed 0.12 inches at any location within the bay. Also, the large volume of water passing the bridge site during each tide (up to 2×10^8 cubic feet) will dilute any metals and nutrients released from the sediments to several orders of magnitude below their detection limit. The extra oxygen demand exerted by the resuspended bottom sediments is also expected to be several orders of magnitude lower than ambient biochemical oxygen demand of the water column.

INTRODUCTION

The North Channel bridge (fig. 1) was constructed in 1923 and has since served as a main access route to Rockaway Beach, a major recreation area for residents of New York City. The bridge, which is heavily used during summer, has deteriorated sufficiently to require replacement.

The proposed method of replacement requires removing 2,145 piles from the present bridge and installing 344 piles for the new bridge. Six to 10 piles



Base from U.S. Geological Survey
State base map, 1974, 1:500,000

Figure 1.--Location and major features of Jamaica Bay.

are expected to be removed each day, and the New York State Department of Transportation estimates that the removal of each pile will cause the resuspension of about 1 ft^3 of bottom sediment. Although bottom sediments east of the bridge in Grassy Bay are heavily contaminated with metals and organic compounds, the chemical quality of bottom sediments in the vicinity of the bridge is unknown. If they are contaminated and consist of particles small enough to be transported long distances, they may adversely affect the relatively healthly biological habitats in sandy areas west of the bridge.

With the proposed bridge, the cross-sectional area of the channel occupied by the bridge piers and piles will be decreased from 15 percent to 7.5 percent. However, the proposed configuration may change the circulation patterns within the bay, which could cause scour and result in the transport of possibly contaminated sediments to the biological habitats to the west (fig. 1).

In 1984, the U.S. Geological Survey, in cooperation with New York State Department of Transportation, began a study to assess the hydraulic regime in the immediate vicinity of the bridge and the physical and chemical characteristics of the bottom sediments. The Survey then used this information in a semiquantitative analysis of the possible effects of bridge replacement on the water-volume transport, water quality, and sediment-transport characteristics of the bay.

The study included measurements of tidal stage and velocity at the North Channel bridge during the spring of 1984 to document the present tidal flow characteristics at the bridge and to estimate changes in these characteristics that might result from changes in the bridge configuration. This information was also used to identify the potential for scour at the cross sections of the proposed bridge.

The study also included measurement of the biochemical oxygen demand (BOD) of suspended bottom sediments, an analysis of particle-size distribution and settling velocity of the bottom sediments, a determination of the amounts of metals and nutrients released to the water column from the suspended bottom sediments, and an analysis of the concentration of selected metals and organic compounds in the bottom sediments. This information was used with estimates from the New York State Department of Transportation on the timing and amounts of bottom sediments to be suspended by bridge construction in an analysis of the resulting water quality and the transport of the suspended bottom sediments.

Purpose and Scope

This report summarizes the results of the investigation. The section on hydraulic characteristics describes the effects of the present and proposed bridges on water transport and bay-bottom configuration. Data on water transport during a 1-month period and the effects of flow constriction during spring tides are summarized in tables; maps of the bay-bottom configuration in the vicinity of the two bridges are included. The section on sediment characteristics describes the physical and chemical quality of the sediments as well as the transport and redeposition of sediments that would be suspended during bridge replacement. The section on sediment also includes data on the oxygen demand and metal and nutrient exchange; a map shows the probable extent of the sediment redeposition.

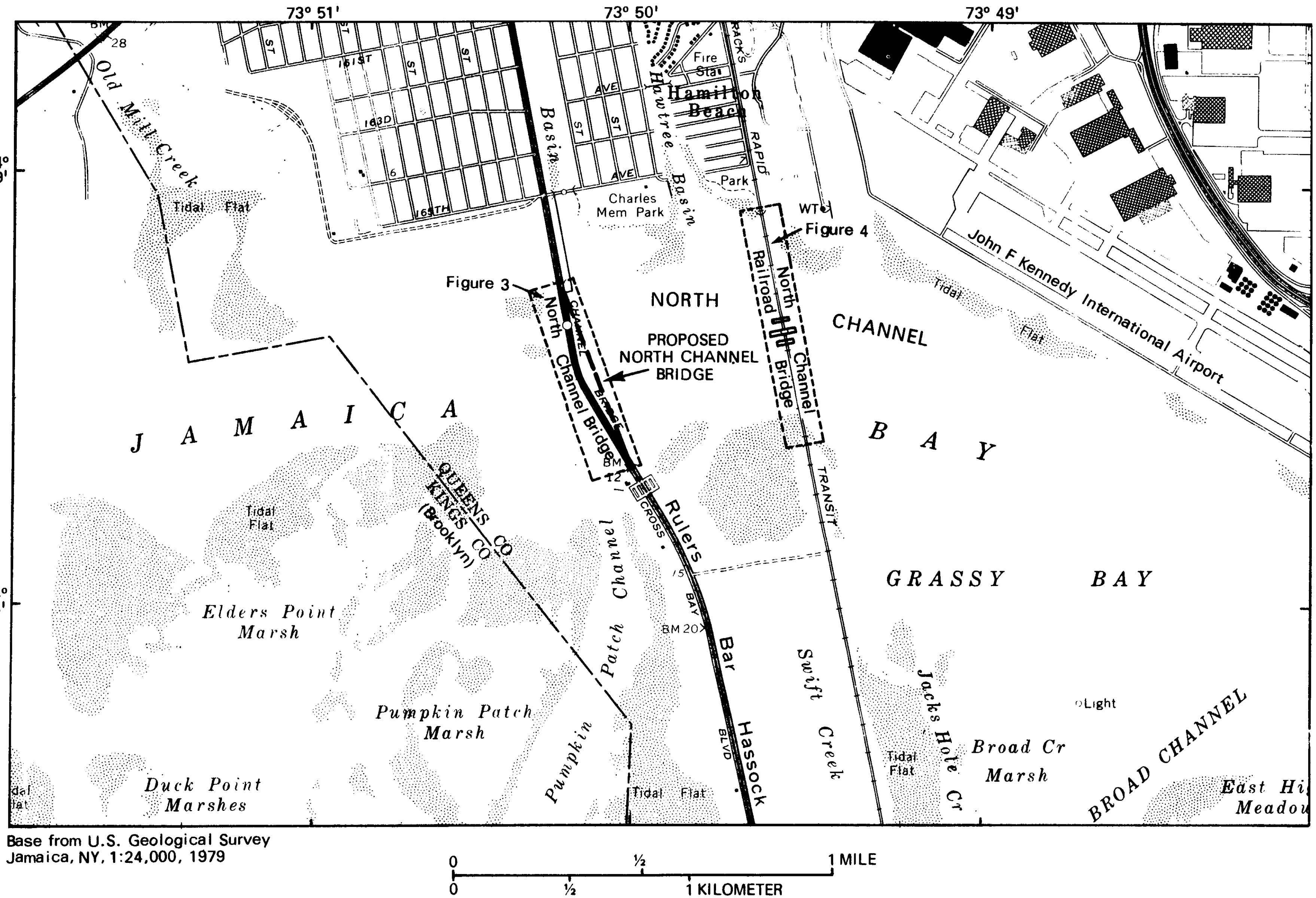


Figure 2.--Major features of North Channel bridge vicinity.

Seasonal and annual variations in flow patterns and rates could not be taken into account because the data-collection period was limited to 1 month; therefore, the projections of longer term tidal patterns, channel scour, and sediment transport and deposition given herein must be considered as semiquantitative only. These estimates indicate the relative magnitude of bridge-replacement effects rather than the exact values.

SITE DESCRIPTION

Jamaica Bay is a 13,000-acre estuary bordered on the north by Brooklyn and Queens, on the east by Kennedy Airport, on the south by Rockaway Beach, and on the west by Floyd Bennett Field (fig. 1). The southwest corner of the bay opens to the Atlantic Ocean through Rockaway Inlet. The bay is roughly circular, with deep navigable channels along the outer circumference and 4,000 acres of relatively undisturbed marshland in the center.

Jamaica Bay is bisected by Cross Bay Boulevard and the transit railroad causeway to the east, both of which pass through the community of Broad Channel and end at Rockaway Beach to the south. The North Channel bridge extends about 2,000 ft across North Channel and connects Rulers Bar Hassock with Howard Beach about 1/2 mi west of Grassy Bay (fig. 2). Beneath the bridge, North Channel ranges in depth from 5 to 22 ft at mean low water.

Tides

A full tidal cycle occurs about every 12.4 hours in Jamaica Bay, with high and low tides almost twice daily. The mean tidal range is about 5 ft; spring tides are about 20 percent greater than the mean. The mean tidal prism (volume of water between mean high and mean low tide) is 2.51×10^9 ft^3, or about 36 percent of the total bay volume at midtide. The geometric configuration of Jamaica Bay, which is roughly circular with scattered landmasses in its center, gives rise to complex circulation patterns during each tidal cycle. The extensive tide-induced movement of water in Jamaica Bay creates sufficient turbulence to cause nearly complete vertical mixing in most areas of the bay (Feuerstein and Maddaus, 1976, p. 200). In addition, the movement of water from the main channels to the shallow marshy areas and back during the flood and ebb cycle causes considerable lateral mixing throughout the bay (Leendertse and Gritton, 1971, p. 69).

Land Use

The drainage area to Jamaica Bay is mostly high- to medium-density residential with small areas of light and heavy industry. Approximately 1.64 million people live within the drainage area, and their treated sewage is discharged to the bay. Effluents from sewage-treatment plants constitute the major source of nontidal flow to the bay. In dry weather, these sources discharge 220 Mgal/d of treated sewage--about 1 percent of the mean tidal prism (Feuerstein and Maddaus, 1976, p. 20.)

Dredging

Before the turn of the 20th century, Jamaica Bay was a productive estuary consisting of about 25,000 acres of shallow marshland that provided clams, oysters, lobsters, crabs, and fish to New York City. After the beginning of the 20th century, however, the bay and its environs underwent extensive development. Dredging began in the outer channels to create ship channels 1,000 to 1,500 ft wide and 30 to 40 ft deep. The fill from the dredging was used to raise the marshes along the periphery of the bay. The commercial production of seafood was eventually destroyed by this dredging and also by the increased discharge of untreated sewage to the bay. Although commercial seafood production was forbidden for health reasons in the early 1920's, individuals have continued to harvest seafood from the bay (Fay and others, 1971).

Additional dredging was done in later years, and the fill was used to create Floyd Bennett Field and Kennedy Airport (fig. 1). With the addition of solid-waste landfills along North Channel in Brooklyn and Queens, nearly all of the 12,000 acres of marshland along the periphery of the bay have been destroyed (Fay and others, 1971). Dredging in Grassy Bay supplied 50 x 10^6 yd^3 of fill for Kennedy Airport and left a deep pool to which the Jamaica Sewage Treatment Plant discharges about 96 Mgal/d of treated sewage. Extension of runway 4-22 at Kennedy Airport in the mid-1960's (fig. 1) also altered the natural tidal circulation pattern through Grassy Bay and helped transform it into a sluggish pool in which fine-grained sediments and their associated contaminants readily settle (Feuerstein and Maddaus, 1976; Fay and others, 1971).

The effect of 80 years of dredging has been to increase the mean depth of the bay from about 3 ft to 16 ft, with a corresponding increase in the residence time of conservative substances from 10 days to an estimated 35 days (Fay and others, 1971, p. 53). Approximately 70 percent of the present water volume of the bay is the result of dredging (Feuerstein and Maddaus, 1976, p. 18).

In spite of the repeated dredging of Jamaica Bay, the extensive development surrounding it, and the large amount of treated sewage entering it, the bay remains an important natural resource. It contains more than 60 species of fish and shellfish and serves as one of the few remaining nurseries for oceanic fishes in the New York City area. It also contains relatively high-quality, sandy benthic habitats in its well-flushed western part. The marshland provides an important feeding and nesting area for birds; approximately 300 bird species have been sighted in the Jamaica Bay refuge (Fay and others, 1971).

HYDRAULIC CHARACTERISTICS

Movement of water in the study area is the means by which dissolved and suspended material may be transported from the bridge-replacement site to habitats where they may have detrimental effects. Evaluation of sediment and chemical transport requires detailed knowledge of tidal hydraulics in the area. Water-transport characteristics were estimated through adaptations of several standard techniques to the conditions at the North Channel highway bridge.

Methods

Two primary factors are needed to calulate water transport--the average speed of the water (typically in ft/s) and the cross-sectional area (in ft^2)

through which it is moving. The product of these two quantities represents water transport, often called discharge, in ft^3. In a tidal environment, measurement of these two quantities is complicated because both vary with time. In this study, the time-varying cross section of flow was calculated from measurements of the bay-bottom configuration by fathometric techniques and measurements of the water-surface altitude by float-operated water-level recorders. From this information, the cross section of flow at any time during the tidal cycle can be computed. The data on bay-bottom configuration were also used to assess scour patterns around the piles of the highway bridge and of nearby railroad bridges.

The time-varying average velocity was computed from records of two recording velocity meters in conjunction with velocity measurements made at many sites within the cross section throughout a tidal cycle.

One recording velocity meter provided an index velocity during flood tides; the other provided values during ebb tides. Both readings were calibrated from the intensive tidal-cycle measurements to produce estimates of the average velocity in both directions. Because each meter measured both flood and ebb velocities, some redundancy was inherent in the velocity-measurement program.

To evaluate whether the present bridge acts as a constriction to flow, three water-level recorders were used to determine the water-surface profile under the bridge. (A significant constriction will produce a measurable slope in the water surface over a relatively short distance. The greater the slope, the greater the degree of constriction.)

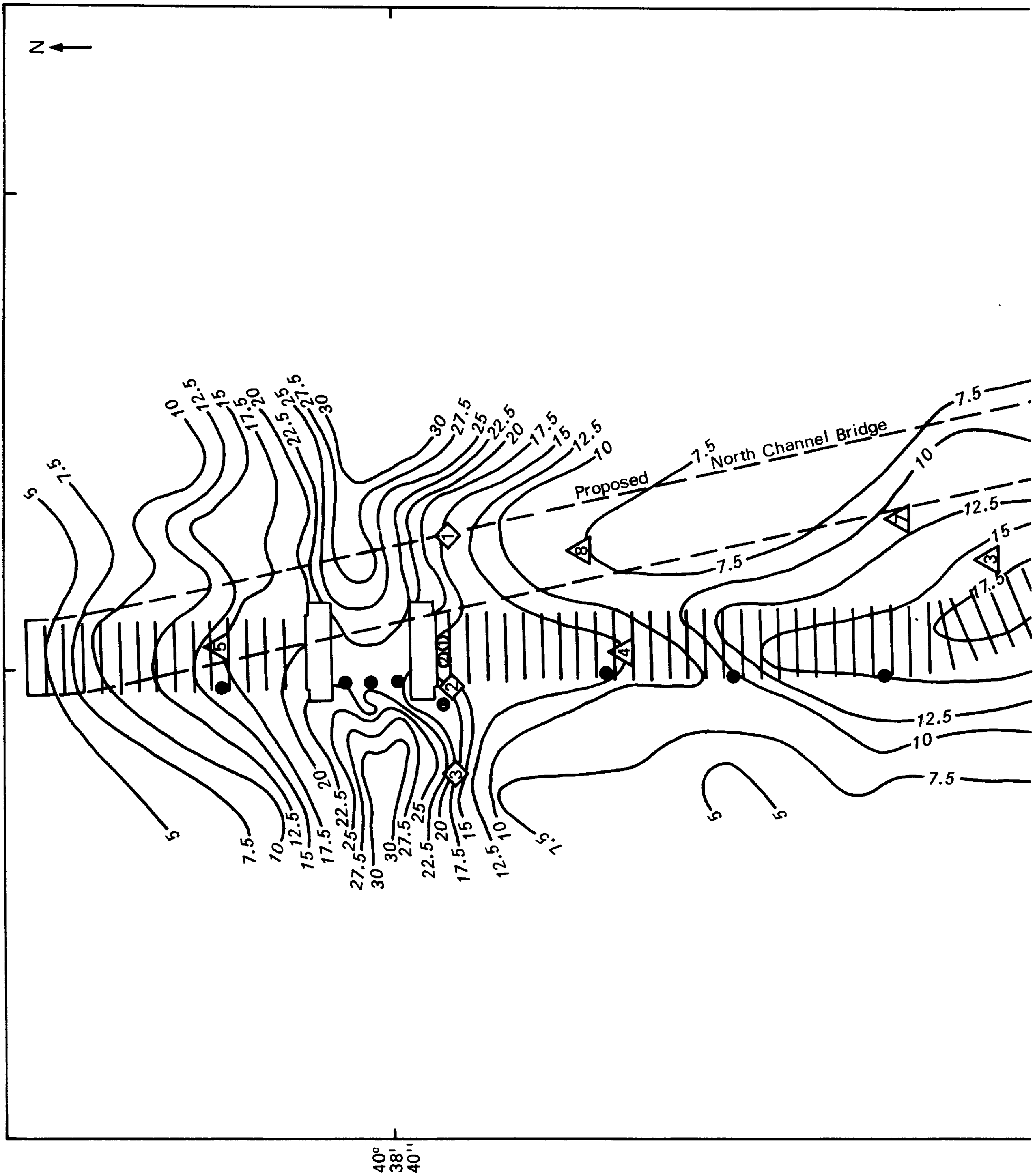
Measured water transport, water-surface slope, and bottom configuration at the present bridge and bottom configuration at the railroad bridge were used in conjunction with known specifications for the proposed bridge to project changes that the bridge replacement may incur.

Data Collection

Bay-Bottom-Configuration

Fathometer data were collected May 16, 1984 and adjusted to the National Geodetic Vertical Datum of 1929 (mean sea level) with water-level data from a recording tide gage at 50 ft west of the centerline of the North Channel bridge (fig. 3). Two traverses parallel to the bridge and perpendicular to the flow were made on both sides of the North Channel bridge and the North Channel railroad bridge. The two traverses were approximately 10 ft and 150 ft from the sides of the bridges. Several additional traverses were made perpendicular to the bridge and parallel to the flow at selected locations where the boat containing the fathometer equipment could pass safely under the bridges.

The bay-bottom configuration in the vicinity of the present North Channel bridge and proposed bridge is shown in figure 3; the bay-bottom configuration in the vicinity of the railroad bridge is shown in figure 4.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73° 50'00''
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40° 38' 40''
Proposed
North Channel Bridge

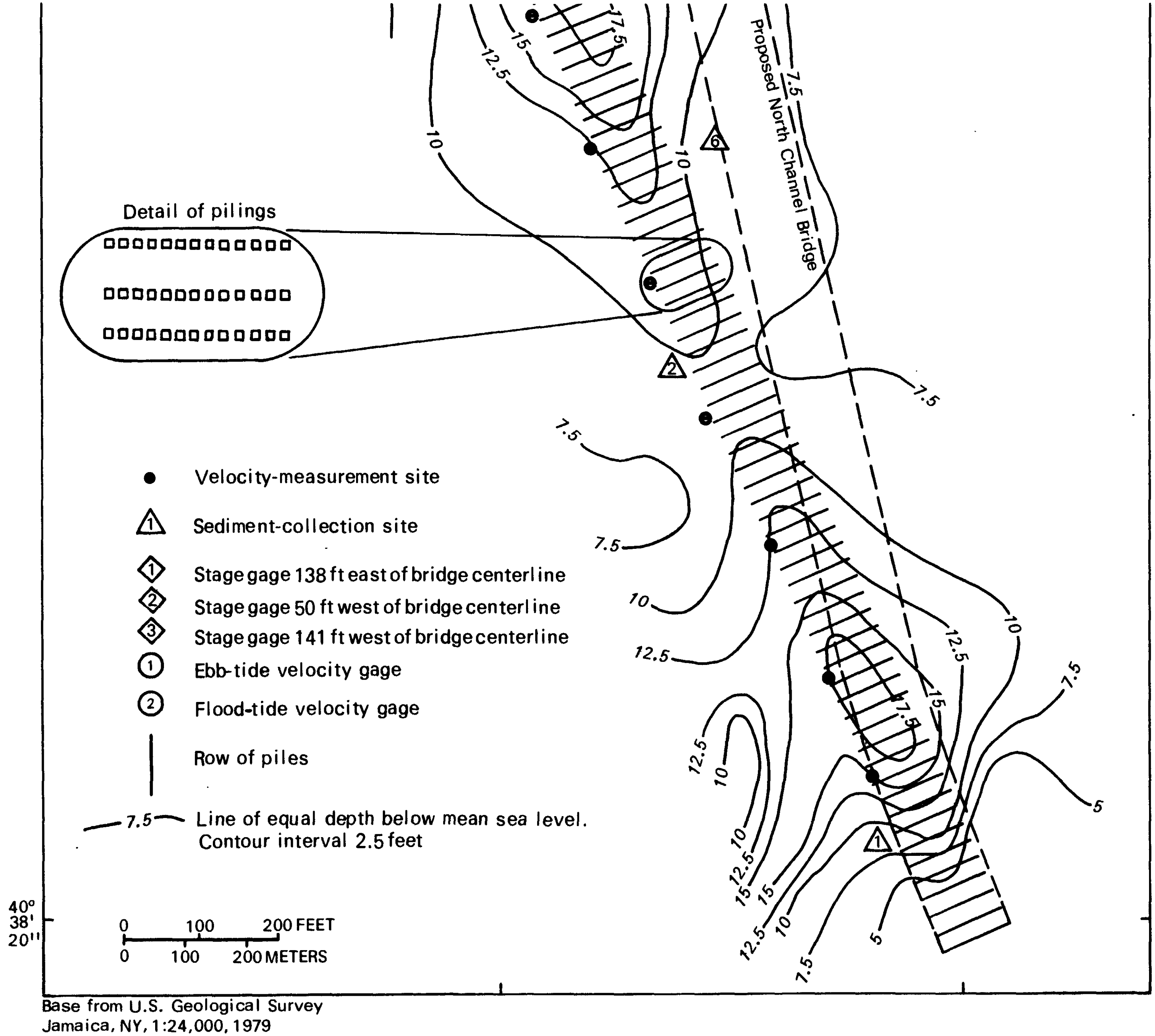
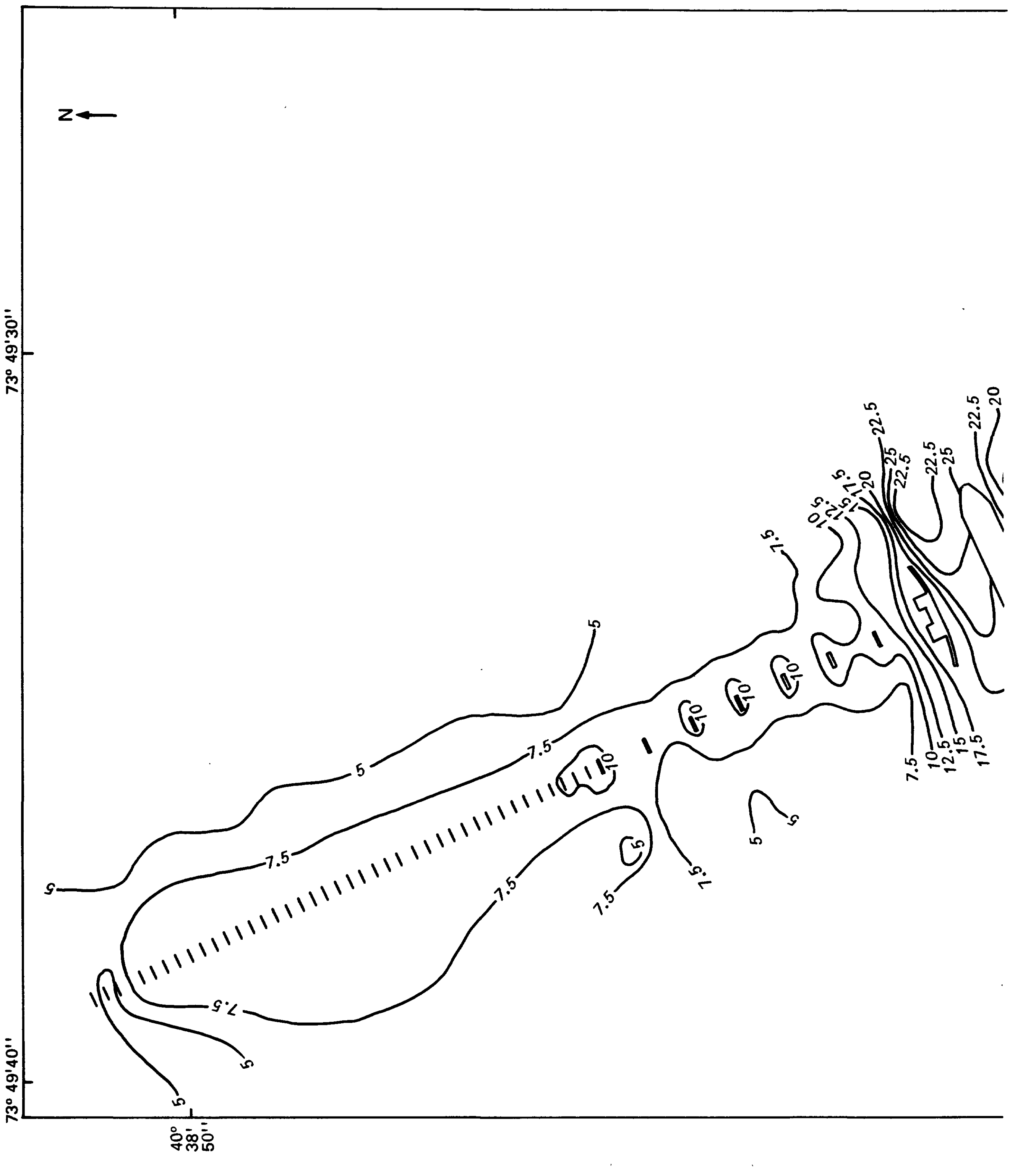


Figure 3.--Location of gages and sediment-collection sites and bay-bottom configuration at present and proposed North Channel bridge. (Location is shown in fig. 2.)


N
73° 49'30''
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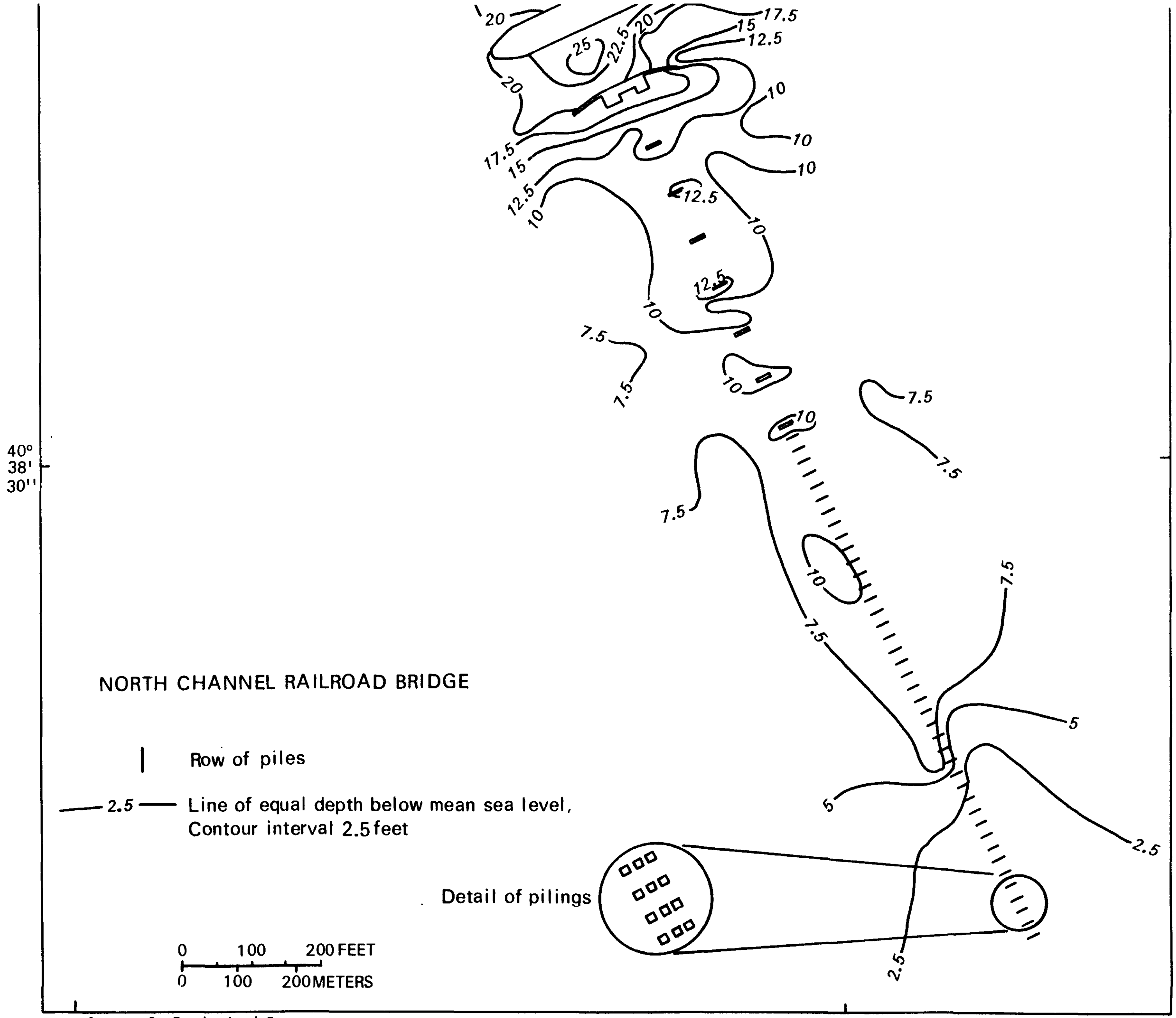

Base from U.S. Geological Survey
Jamaica, NY, 1:24,000, 1979

Figure 4.--*Bay-bottom configuration at North Channel railroad bridge.* *(Location is shown in fig. 2.)*

Tidal Stage

Three stage-recording gages were placed at the 88th row of piles and aligned parallel to the flow (fig. 3). The intakes to the stage gages were placed 141 ft west of the bridge centerline, 50 ft west of it, and 138 ft east of it. The stage gages were programed to record instantaneous water level every 5 minutes. The datum for the stage gages was established April 13, 1984, and data were recorded from then until May 15, 1984 at the two outermost gages. The stage gage 50 ft west of the bridge centerline was maintained until May 16, 1984 to record stage during the operation of the fathometer. Data records from all three stage gages were complete during the above-mentioned periods.

Tidal Velocities

Two recording electromagnetic flow meters that provide index velocities were placed 5 ft south of the 89th pier at the centerline of the bridge (fig. 3) at an altitude of -6.1 ft. This altitude was approximately 3 ft below the lowest recorded stage to minimize the effect of wave action.

The meters were set to sense velocity for 10 seconds approximately once every minute for a 5-minute period and to record the computed average 5-minute velocity. The meters were operational from April 12, 1984 through May 15, 1984. Velocities ranged from 0.0 ft/s at slack tides to slightly less than 2.5 ft/s during peak flood- or ebb-tide velocities.

The velocity meters provided a complete tidal-velocity record except when the flood-tide velocity meter failed intermittently during April 12-18, 1984. Because both meters can record flow in either direction, data from the ebb-tide velocity meter was used to reconstruct the missing flood-tide velocities. A linear regression of flood-tide index velocities in relation to ebb-tide index velocities yielded the following relationships:

$$V_{Flood\text{-}index} = -1.1672\ V_{Ebb\text{-}index} \qquad (1)$$

where: $V_{Flood\text{-}index}$ = flood-index velocity at flood-tide velocity meter,

$V_{Ebb\text{-}index}$ = ebb-index velocity at the ebb-tide velocity meter.

The correlation coefficient is 0.996.

Flow velocity was measured at the North Channel bridge during a complete tidal cycle on April 18, 1984, to develop a mathematical relationship between the average velocity in the bridge cross section and the recorded index velocities. Velocity was measured at the midpoint of 15 preselected sections every 30 minutes. Twelve of the sections were bounded by adjacent rows of piles and were 22 ft in width; the other three divided the main channel into 33-ft segments. (Locations of the 15 measuring sections are shown in fig. 3.) Velocity measurements were made at points 20 percent and 80 percent of the total depth at 10 of the sections, and detailed measurements were made at points 10, 20, 50, 80, and 90 percent of the total depth at the remaining five sections.

The five sections chosen for detailed vertical measurements were changed every half hour so that all 15 sections were measured by the third series of measurements. Supplemental velocity measurements were made continuously during the tidal cycle at all sections except the three in the main channel. Each section was divided into five subsections, including the midpoint, and velocity observations were made at points 20 and 80 percent of the total depth. This data set provided sufficient information to calculate discharges and average velocity at 30-minute intervals for each of the 12 sections.

Analysis and Conclusions

Water Transport

Measured tidal velocity and cross-sectional data were used to calculate water transport. Linear relationships between the measured midpoint velocities and the average section velocities calculated from the supplemental velocity measurements were developed. The relationships for each of the 12 sections were applied to the midpoint velocities to obtain average section velocities at 30-minute intervals. Average section velocities were then assigned by interpolation to the remaining 92 sections bounded by adjacent rows of piles. Cross-sectional areas of all sections were computed from fathometer and tidal stage data, and average section velocities for all sections were then used to compute discharges at 30-minute intervals through the bridge cross section, excluding the main channel. Velocities measured at 30-minute intervals at the main channel were used to calculate discharges directly. The discharges were summed, and an average velocity for the entire bridge cross section at each 30-minute interval was calculated by dividing each computed discharge by the computed cross-sectional area for that time. These average velocities were then plotted against the recorded index velocities. The following relationships were developed by linear regression:

$$\overline{V}_{Flood} = 0.574 \, V_{Flood\text{-}Index} \qquad (2)$$

$$\overline{V}_{Ebb} = 0.609 \, V_{Ebb\text{-}Index} \qquad (3)$$

where: $\overline{V}_{Flood}$ = average flood-tide velocity at bridge cross section,
$\overline{V}_{Ebb}$ = average ebb-tide velocity at bridge cross section,
$V_{Flood\text{-}index}$ = flood index velocity at the flood-tide velocity meter,
$V_{Ebb\text{-}index}$ = ebb index velocity at the ebb-tide velocity meter.

The correlation coefficients for equations 2 and 3 are 0.997 and 0.986, respectively. Relationships between average velocities and index velocities were used to obtain average cross-section velocities during flood and ebb tides every 5 minutes. Cross-sectional areas for both sides of the North Channel bridge and for all ranges in stage were developed from the fathometer data. The cross-sectional areas on the west side of the bridge were used with the flood tide, and the cross-sectional areas on the east side were used for the ebb tide. The 5-minute stage data at the tide gage 50 ft west of the bridge centerline was correlated with the cross-sectional areas. The average 5-minute velocity was then multiplied by the cross-sectional area and 5-minute time interval to yield the volume of water passing through the bridge cross section in 5 minutes.

Beginning at 2030 hours on April 15, 1984, and continuing until 2005 hours on May 14, 1984, computed 5-minute volumes of water transport were summed for each successive flood and ebb tide. The results, shown in table 1, indicate that the net transport of water through the North Channel bridge cross section was variable but predominantly west to east. (A positive value indicates a west-to-east direction.)

Table 1.--Summary of water transport through North Channel bridge cross section, Jamaica Bay, N.Y.

[Transport values are in cubic meters per second.]

Date and time[a]				Length of tidal cycle	Net transport for each successive tidal cycle	Net transport (as percentage of total tidal volume	Time-weighted average of net transport
month	day	hour	minute	(h)	(ft^3 x 10^8)[b]	passing bridge)	(ft^3 x 10^8)[b]
4	15	20	30	--	--	--	--
4	16	9	10	12.67	-1.15	12.4	-1.15
4	16	21	10	12.00	-.47	5.8	-.82
4	17	9	30	12.33	-1.78	21.8	-1.14
4	17	21	40	12.17	-.51	7.0	-.98
4	18	10	20	12.67	-1.94	24.6	-1.18
4	18	22	50	12.50	1.15	13.4	-.79
4	19	11	15	12.42	-.15	1.7	-.70
4	19	23	45	12.50	.99	12.4	-.48
4	20	11	40	11.92	.04	.6	-.43
4	21	00	15	12.58	.39	6.4	-.34
4	21	12	20	12.08	-1.53	24.6	-.45
4	22	2	10	13.83	1.13	20.3	-.30
4	22	14	20	12.17	.65	10.0	-.23
4	23	1	30	11.17	3.33	31.4	-.00
4	23	15	35	14.08	.26	8.0	.02
4	24	2	15	10.67	3.29	[c]93.6	.19
4	24	14	40	12.42	.12	3.2	.19
4	25	3	25	12.75	-.53	10.6	.15
4	25	15	40	12.25	-.99	18.0	.09
4	26	5	0	13.33	.56	10.2	.11
4	26	18	0	13.00	1.57	28.4	.19
4	27	5	50	11.83	.91	19.8	.22
4	27	18	25	12.58	.99	17.9	.25
4	28	6	45	12.33	1.65	29.5	.31

a Eastern Standard Time.
b Positive values indicates west-to-east movement.
c Affected by storm.

Table 1.--Summary of water transport through North Channel bridge cross section, Jamaica Bay, N.Y. (continued).

Date and time[a]				Length of tidal cycle (h)	Net transport for each successive tidal cycle ($ft^3 \times 10^8$)[b]	Net transport (as percentage of total tidal volume passing bridge)	Time-weighted average of net transport ($ft^3 \times 10^8$)[b]
month	day	hour	minute				
4	28	18	45	12.00	1.56	23.9	.36
4	29	7	5	12.33	1.37	21.0	.40
4	29	19	25	12.33	1.53	21.3	.44
4	30	7	40	12.25	.38	4.9	.44
4	30	19	35	11.92	1.80	24.7	.48
5	01	7	35	12.00	-.19	2.5	.46
5	01	14	55	12.33	.08	1.1	.45
5	02	9	15	13.33	.01	.1	.43
5	02	21	10	11.92	1.15	4.8	.45
5	03	10	0	12.83	.65	8.1	.46
5	03	22	40	12.67	1.93	25.1	.50
5	04	11	10	12.50	.86	15.7	.51
5	04	21	25	10.25	1.74	25.2	.54
5	05	11	20	13.92	-1.45	19.9	.48
5	05	23	20	12.00	1.11	15.7	.50
5	06	12	10	12.83	.35	5.8	.49
5	07	00	30	12.33	1.66	27.5	.52
5	07	13	05	12.58	.16	2.8	.51
5	08	1	35	12.50	1.76	33.1	.54
5	08	14	00	12.42	.68	11.7	.55
5	09	3	10	13.17	1.93	34.1	.58
5	09	15	00	11.83	-1.20	19.1	.54
5	10	3	5	12.08	.35	4.7	.54
5	10	16	20	13.25	.96	12.2	.55
5	11	4	35	12.25	1.13	16.5	.56
5	11	17	25	12.83	1.62	19.9	.58
5	12	5	30	12.08	1.33	18.4	.60
5	12	18	20	12.83	1.58	18.8	.61
5	13	6	40	12.33	.90	10.3	.62
5	13	19	20	12.67	2.28	25.4	.65
5	14	7	30	12.17	.44	5.7	.65
5	14	20	5	12.58	2.01	25.5	.67

a Eastern Standard Time.
b Positive values indicates west-to-east movement.
c Affected by storm.

One synodic month, or 29.5 ± 0.5 days, was used to evaluate the net or long-term water-transport characteristics. The synodic month was chosen because the ranges in tides are nearly repetitive after this period if influences of wind and atmospheric pressure are small (Strahler, 1969). The synodic month studied began and ended during spring-tide conditions. The average net transport per tidal cycle for the synodic month was 0.67×10^8 ft^3 (which is subject to minor error).

The findings of this study seem to contradict previous work that shows the net transport of water at the North Channel bridge to be east to west or negligible. Computed water transport at the North Channel bridge simulated by a two-dimensional estuarine model (Leendertse, 1972) shows a weak east-to-west transport of 1,400 ft^3/s. Wind speed and direction were also found to greatly influence the net transport. The Federal Highway Administration and New York State Department of Transportation (1982) state that the circulation is counterclockwise, which also implies a net east-to-west movement. Feuerstein and Maddaus (1976) state that the net circulation of water was originally counterclockwise but became negligible with the extension of runway 4-22 at John F. Kennedy International Airport in the mid-1960's. During the synodic month studied, however, the net transport of water was from west to east at 1,500 ft^3/s, assuming an average tidal cycle of 12.42 hr.

Bridge Constriction

One aspect of major importance is the effect that changes in bridge geometry may have on the degree of flow constriction through the bridge cross section and possible implications regarding changes to the net transport of water. Data collected from the three tide gages (fig. 3) and data from Leendertse (1972) were used to evaluate the present constriction at the bridge and project to the probable effects of the proposed bridge on flow constriction and net water transport.

Leendertse (1972) shows that differences in stage slightly greater than 0.40 ft occur over a 4.7-mi segment of Jamaica Bay closely centered at the North Channel bridge. These differences were recorded during a 5-day period that was not during spring-tide conditions (U.S. Department of Commerce, 1969). Analysis of stage data collected during spring-tide conditions indicates that the maximum differences in stage between the tide gages 141 ft west and 138 ft east of the bridge centerline is less than or equal to 0.15 ft (table 2). Under these circumstances, the contributing percentage of head loss in the vicinity of North Channel bridge is 38 percent or less.

As mentioned above, the differences in stage reported by Leendertse (1972) did not occur during spring-tide conditions. Differences that occur during spring tides are likely to be greater, and the contributing percentage of head loss in the vicinity of North Channel bridge will always be less than 38 percent. More accurate estimates of the percentage at the upper limit cannot be given because the necessary data were not available for comparison.

The total stage difference of 0.15 ft at the North Channel bridge indicates that the bridge is probably not constricting the flow. Where stage differences are less than 0.50 ft, flow is probably not constricted. It has been recommended that indirect discharge calculations based on stage differences of 0.50 ft or less be avoided (Matthai, 1967).

The contributing percentage of head loss in the vicinity of North Channel bridge is not significant, as explained above, nor are the additional head losses observed at the bridge great enough to constrict the flow. In all probability the observed head losses are the result of channel constriction. The proposed bridge, with only 50 percent as much gross area occupied by piles and piers, should not significantly constrict the flow or alter the net water transport.

Table 2.--Maximum differences between stage at tide gage 141 feet west and 138 feet east of bridge centerline during spring tides.

[Locations are shown in fig. 3.]

Date and time[1] month	day	hour	minute	Direction of tide	Average 5-minute velocity at bridge cross section (ft/s)	Average 5-minute discharge at bridge cross section (ft^3/s)	Water-surface elevation (ft)* Gage 141 ft west	Gage 50 ft west	Gage 138 ft east	Difference in water surface between 141-ft west and 138-ft west (ft)
4	16	00	15	Ebb	1.36	36,900	-0.49	-0.50	-0.41	-0.08
4	16	04	10	Flood	.80	24,800	-.06	-.17	-.21	.15
4	16	12	25	Ebb	1.18	35,200	.24	.24	.31	-.07
4	16	17	15	Flood	.80	28,000	1.54	1.47	1.45	.09
5	13	21	25	Ebb	0.71	24,300	1.84	1.84	1.91	-0.07
5	14	3	20	Flood	1.17	33,600	-.13	-.20	-.24	.11
5	14	11	10	Ebb	.82	22,300	-.91	-.91	-.85	-.06
5	14	15	25	Flood	1.12	33,100	-.74	-.83	-.88	.14

[1] Eastern Standard Time.
* Feet above or below mean sea level.

Bottom Scour

A qualitative evaluation of a probable bay-bottom configuration at the proposed North Channel bridge is based on the observed bay-bottom configurations at the present North Channel bridge and railroad bridge.

Bathymetry data collected at the North Channel bridge indicate large, uniformly scoured areas on either side of the main-channel piers (fig. 3). The largest areas of scour are between the 10th and 20th row of piles and between the 45th and 65th row of piles, with bottom depths ranging to about 18 ft below mean sea level. The main channel is also deep because it is dredged to maintain a navigation channel (Fay and others, 1971). The larger scour areas coincide with areas of greater velocity, as determined from the velocity measurements of April 18, 1984, and may be extensions of Pumpkin Patch Channel and the unnamed channel between Pumpkin Patch Marsh and Elders Point Marsh (fig. 2). No pronounced scour holes were detected near individual piers of rows of piles. The greatest depths in the sand-bottom channel are generally parallel to the direction of tidal flow and directly below the centerline of the bridge.

Two scour mechanisms are evident from the bay-bottom configuration at the present bridge. General scour is caused by the increase in velocity resulting from a constricted cross section, whereas local scour that results from vortices and eddies caused by an obstruction such as a pier or pile (Richardson and others, 1975). The effects of general and local scour at North Channel bridge are difficult to distinguish. Undoubtedly, slight increases in velocity result from the constriction at the bridge and cause some general scour. Local scour is also present, although its effects are superimposed on the general scour and are not readily identified. The effects of local scour are transferred from one row of piles to another to produce a smooth channel bottom similar to that caused by general scour. The closeness of the rows of piles to each other makes this possible.

Collection of bathymetry data in the vicinity of the North Channel railroad bridge was considered essential because the piers are similar in design and spacing to those of the proposed bridge. On either side of the two main channels are seven round-nosed piers followed by 41 rows of three 2-ft piles (fig. 4). The bay-bottom configuration here differs markedly from that of North Channel bridge. Large scour holes ranging to depths of 10 to 13 ft below mean sea level, unquestionably the result of strong local scour, surround most of the seven round-edged piers on either side of the main channels but disappear within the 41 rows of piles on either side of the main channels. As at North Channel bridge, the local scour effects at the 41 rows of piles are not readily evident because they are influenced by the closeness of the adjacent rows of piles. The result is a smooth bay bottom without pronounced scour holes surrounding the rows of piles.

General conclusions regarding the bay-bottom configuration at the proposed bridge are derived primarily from observations of the bay-bottom configurations of North Channel bridge and North Channel railroad bridge. Local scour at the proposed North Channel bridge should be slightly less than at the present North Channel bridge because the proposed bridge calls for a 50-percent decrease in the total area of piles and piers. However, unlike the present conditions, local scour at the proposed bridge will be easily identified by pronounced scour holes surrounding piers. The similarity of pier design and spacing of the North Channel railroad bridge and the proposed bridge is the basis for this assumption. Because the proposed bridge is similar in location and total length to the present bridge, the width constriction should remain unchanged, and thus the degree of general scour should also remain unchanged.

No effort has been made to identfy the forces responsible for the types of scour observed; to do so was beyond the scope of the study.

SEDIMENT CHARACTERISTICS

The sediment study consisted of experiments to assess the chemical quality of sediments in the vicinity of the North Channel bridge, the effects that resuspension of these sediments might have on the water quality of the bay, and the potential for these sediments to be transported away from the site during bridge replacement. A sediment-oxygen-demand experiment was done to determine whether the oxygen demand of the resuspended bottom sediments could lower the dissolved oxygen in the water column to levels low enough to be detrimental to fish. A metals and nutrient-exchange experiment was done to determine whether metals would be released from the bottom sediments to the water column in amounts that could be toxic to fish and whether enough nutrients would be released to contribute to an algal bloom. A particle-size analysis and settling-velocity experiments were conducted to estimate the approximate distance that resuspended bottom sediments could travel before settling during average flow conditions. The concentrations of selected metals and organic compounds in the bottom sediments were measured to determine whether these constituents could be transported by the resuspended sediments in sufficient quantities to be detrimental to healthy benthic habitats west of the bridge site. Where background data were adequate, the results from these experiments were compared to ambient conditions in North Channel and elsewhere in the bay.

Data Collection

Bottom-sediment and water samples were collected at the bridge site on March 28, 1984. Five bottom-sediment samples (sites 1-5, fig. 3) were taken from under the bridge at approximately 500-ft intervals, and three bottom-sediment samples (sites 6-8) were taken 50 to 100 ft from the eastern side of the bridge in the location of the proposed bridge. Raw-water samples were taken in the vicinity of site 4.

A 2-in-diameter piston-core sampler was used to collect two 18- to 24-inch bottom-sediment core samples at each site. At site 3, oyster-shell debris prevented the core sampler from penetrating into the bottom sediments. A Ponar[1] grab sampler was used to sample the upper 4 in. of bottom sediment at this site.

At each site, the piston or Ponar sampler was emptied into a plastic tub, and the bottom material was then subsampled. One subsample was collected from bottom material that had not touched the sides of the plastic tub and was placed in a fired glass jar for analysis for organic constituents. A second subsample was placed in a 40-oz air-tight plastic freezer container for further subsampling in the laboratory. The samples were placed in coolers with ice and transported to the laboratory for processing.

At site 4, a Hydrolab 4041 multiparameter water-quality meter was lowered through the water column, and pH, specific conductance, water temperature, and dissolved oxygen readings were taken at 5-ft depth intervals to define the degree of vertical mixing and to establish whether raw-water samples from the surface would be representative of the water column. As indicated in table 3,

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[1] Use of brand names is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

the water column was well mixed; therefore, all raw-water samples were collected at the surface. The raw-water samples were collected during ebb tide in four 5-gal plastic containers that were then placed in coolers with ice and transported to the laboratory.

Table 3.--pH, dissolved-oxygen concentration, specific conductance, and temperature of water samples taken at 5-ft depth intervals in the water column at North Channel bridge, Jamaica Bay, N.Y., March 28, 1984.

Depth (ft)	Dissolved oxygen (mg/L)	Specific conductance (μS)	Water temperature (°C)	pH (standard units)
1	13.1	38,200	6.1	8.3
5	12.8	38,300	6.1	8.3
10	12.5	38,400	6.1	8.3
14	12.3	38,400	6.1	8.3

Laboratory Methods

Sediment Oxygen Demand

The sediment oxygen demand was calculated through a variation of the "direct method" of measuring biochemical oxygen demand. As stated by the American Public Health Association (1980, p. 483):

> The biochemical oxygen demand (BOD) determination is an empirical test in which standardized laboratory procedures are used to determine the relative oxygen requirements of wastewaters, effluents, and polluted waters. The test measures the oxygen required for the biochemical degradation of organic material (carbonaceous demand) and the oxygen used to oxidize inorganic material such as sulfides and ferrous iron. It also may measure the oxygen used to oxidize reduced forms of nitrogen (nitrogenous demand) unless their oxidation is prevented by an inhibitor.
>
> The method consists of placing a sample in a full, airtight bottle and incubating the bottle under specified conditions for a specific time. Dissolved oxygen (DO) is measured initially and after incubation. The BOD is computed from the difference between initial and final DO.

The direct method, which uses no dilution water, was used because it involves no modification of the sample and therefore produces results as similar as possible to those in the natural environment (Sawyer and McCarty, 1978, p. 421).

A 5-cm^3 subsample was taken from each sediment sample and placed in separate 1-gal plastic containers along with 2,200 mL of Jamaica Bay raw water that had been chilled during transport and allowed to adjust to room temperature (20°C) in the laboratory. The mixture was shaken vigorously for 60 seconds and decanted into seven 300-mL BOD bottles. The BOD bottles were then capped, sealed, and placed in an incubator set to 20°C. Immediately thereafter, a

2,200-mL sample of raw water with no added sediment was shaken vigorously and decanted into seven 300-mL BOD bottles. The dissolved-oxygen concentration of the raw water was immediately measured in one of these BOD bottles by a Hach Winkler titration kit, and the remaining six were placed in the incubator.

After all samples had been processed, the instantaneous oxygen demand of each sediment-water mixture and the raw water was measured. A single BOD bottle from each seven-bottle set was withdrawn from the incubator within 6 hours of initial mixing, and the dissolved-oxygen concentration was measured. On each of the 5 succeeding days thereafter, the dissolved oxygen concentration was measured in one bottle from each seven-bottle set. The remaining bottles were then shaken to resuspend the sediment and simulate the well-mixed condition observed in Jamaica Bay.

Metals and Nutrient Exchange

A mixing experiment with sediment and water was conducted to determine the amount of metals and nutrients that may be released from the bottom material to the water column or adsorbed by the sediments from the water column during suspension. Organic-compound analyses were not done because of difficulties in passing sufficient solution through the silver filter. In addition, the amount of soluble pesticides and PCB's added to the water column from dispersal of the interstitial water and through desorption from resuspended solids has been found to be negligible at sediment-to-water ratios of 1:10 or less (Fulk and others, 1975, p. 3).

The sediment-and-water mixing experiment consisted of mixing 300 mL of sediment with 2,100 mL of chilled raw water in a 1-gal plastic container. The water/sediment mix was shaken periodically over a 24-hour period to keep the sediment in suspension and was kept chilled to minimize microbial uptake of nutrients. The suspension was allowed to settle for 2 hours at the end of the mixing period, and the supernatant was then filtered through a 142-mm diameter, 0.45-μ Millipore acetate filter that had been rinsed with 500 mL of distilled water. The filtrate was then split into one 250-mL dark plastic bottle for nutrient analysis and one 250-mL clear plastic bottle for metals analysis. The nutrient sample was treated with mercuric chloride and chilled; the metal sample was treated with 1 mL of nitric acid. Both were sent to the U.S. Geological Survey's Central Laboratory in Atlanta, Ga., for analysis. Concurrently, two raw-water samples were also filtered, treated, and analyzed for nutrients and metals. A detailed description of the laboratory procedures is given in Skougstad and others (1978).

The quantity of metals and nutrients released from the sediment or adsorbed by the sediment was calculated as the difference between the concentration in the filtered sediment-and-water mixture and in the filtered raw water.

Metals and Organic Compounds in Bottom Sediments

The bottom-material samples collected for analyses for organic compounds were sent chilled to the U.S. Geological Survey Central Laboratory in Atlanta, Ga., where they were analyzed for organochloride and organophosphorus compounds, including polychlorinated biphenyls (PCB's) and polychlorinated naphthalenes (PCN's). These constituents (listed in table 7, p. 30) were selected for analysis because they have either been previously identified in the Jamaica Bay sediment (Feuerstein, 1976, p. 80) or have a strong affinity for particulate material (especially the organic compounds) and have been found associated with bottom sediments at other locations (Rubinstein and others, 1980). A detailed description of the laboratory procedure is given in Wershaw and others (1983).

The bottom-material samples were also analyzed for arsenic, barium, cadmium, chromium, copper, lead, mercury, selenium, and zinc. These metals were selected because they are potentially toxic to the indigenous biota or because they have been found elsewhere within the bay (Ramondetta and Harris; 1978, Franz and Harris, 1983). A detailed description of the laboratory procedures is given in Skougstad and others (1978).

Settling Velocity

To determine the potential for sediment transport away from the bridge site after suspension of bottom material, the settling velocity and the particle-size distribution of each bottom-sediment sample were measured by the bottom withdrawal-tube method. During this experiment, the natural conditions of Jamaica Bay were simulated as closely as possible. Native water was used as the settling medium; no chemicals were used for dispersing, flocculating, or oxidizing the sediment, nor was the sample mechanically dispersed. Under these conditions, the variables influencing sediment-particle flocculaton are as close to the actual bay conditions as possible and therefore should yield fairly accurate settling-velocity times. The particle-size data taken under these conditions do not, however, represent the size distribution of the primary sediment particles, but rather that of the aggregated particles.

Eight 12-oz freezer containers were filled with a representative sample of bottom material from each sampling site and sent with 2 gal of raw water to the U.S. Geological Survey Sediment Laboratory in Columbus, Ohio. At the sediment laboratory, each sample was stirred, and a 4- to 9-g representative subsample was withdrawn and wet seived through 1, 0.5, 0.25, 0.125, and 0.062-mm seives with bay water. The sediment fraction that passed through the 0.062-mm sieve was mixed with 500 mL of bay water, shaken for 60 seconds to disperse the sediment, and added to a bottom withdrawal tube for determination of the settling velocity and particle size. A detailed description of settling velocity and particle-size analysis by the bottom-withdrawal method is given in Guy (1969).

Analysis and Conclusions

Sediment Oxygen Demand

The 5-day biochemical oxygen demand (BOD_5) of the sediment-and-water mixture measured during the 5-day incubation experiment ranged from 7.9 mg/L to 9.1 mg/L, and the BOD_5 of the Jamaica Bay raw water measured concurrently was 5.2 mg/L. The oxygen demand of the sediments in the sediment-and-water mixture, calculated by subtracting the BOD_5 of the raw water from the BOD_5 of the sediment-water mixture, ranged from 2.7 mg/L to 3.9 mg/L.

During days 4 and 5 of the incubation, the dissolved-oxygen concentation in the incubation bottles decreased below 0.5 mg/L in three of the eight sets of bottles. Sawyer and McCarty (1978, p. 424) state that BOD is not influenced by oxygen concentrations above 0.5 mg/L, but below that concentration, the rate of oxygen consumption may decrease rapidly. Because the dissolved oxygen concentrations of three of the sample sets decreased below 0.5 mg/L, and several other sets approached this concentration, the oxygen demand of the sediment-water mixture may be greater than the measured values.

To rectify this underestimate, a correction factor was applied to the BOD measurements. According to Nemerow (1974, p. 75), the total biochemical oxygen demand consumed per interval of time at any particular temperature is a constant percentage of the unoxidized material remaining at the end of the previous time period. Nemerow states that the unoxidized organic matter is reduced by 20.6 percent during each successive 24-hr period. This means that after 3 days, 50 percent of the ultimate BOD has been exerted and, after 5 days, 68 percent of the ultimate BOD has been exerted. Therefore the 3-day BOD is 74 percent of the 5-day BOD. Applying this conversion factor and an adjustment for the immediate oxygen demand of the reduced inorganic species contained in the bottom sediments to the observed 3-day BOD values, an estimated 5-day BOD value was calculated from the formula:

$$\frac{(BOD3 - IOD)}{0.74} + IOD = BOD_5 \qquad (4)$$

where: BOD_3 = 3-day biochemical oxygen demand
IOD = instantaneous oxygen demand
BOD_5 = estimated 5-day biochemical-oxygen demand

The estimated BOD_5 values ranged from 0 to 1.6 mg/L or 0 to 19 percent greater than the measured BOD_5 values. The instantaneous, observed daily, and estimated 5-day BOD values are listed in table 4. The estimated BOD_5 values were used in all analyses described below.

To quantify the effect of the bottom-sediment BOD_5 on the water column of Jamaica Bay, the BOD_5 measured in the incubation bottles, in mg/L, must be converted to a weight or volume of sediment basis as follows: If a sediment dry-weight bulk density of 2.00 g/cm^3 is assumed, and 0.71 cm^3 (1.42 g) of sediment is added to each 300-mL incubation bottle, a BOD of 1 mg/L of test solution measured during the incubation converts to 0.21 mg BOD per gram of sediment or 11,894 mg BOD per cubic foot of sediment. The estimated BOD_5 of each sample, in mg/g and mg/ft^3, is included in table 4.

The BOD_5 of the bottom-sediment samples ranged from 0.7 to 1.2 mg/g with a mean of 1.0 mg/g. Feuerstein (1976, p. 163) estimated that the BOD_5 of the bottom sediment in the vicinity of the North Channel highway bridge was between 2 and 4 mg/g. This estimate was based on interpolation between two measuring stations, one about 1/2 mi east of the bridge in Grassy Bay and the other 1/2 mi west of the bridge along the North Channel. The average BOD_5 of the sediments measured at these two stations were 5.94 mg/g and 0.73 mg/g, respectively, indicating that the BOD_5 of the bottom material at the bridge resembles that of bottom material west along the North Channel more closely than it does the bottom material in Grassy Bay. This also indicates that interpolation of sediment-quality characteristics between two remote stations may not be a valid procedure quality of sediments in relatively close proximity, such as those at the North Channel bridge and those in Grassy Bay, may differ significantly.

The average BOD_5 of the eight bottom-material samples was 53,100 mg/ft^3 of sediment. If it is assumed that up to 10 ft^3 of bottom material may be resuspended each day, and that approximately 2×10^8 ft^3 or 5.7×10^9 L of water passes the bridge during a given flood tide or ebb tide, and that complete mixing occurs over the two tidal cycles each day, the BOD_5 exerted daily on the water column will be 529 g or 9.3×10^{-5} mg/L. This value is insignificant compared to the 2.5 to 3 mg/L average summertime BOD_5 of the water column in the vicinity of the North Channel bridge (Feuerstein, 1976, p. 48). The BOD_5 of the bottom sediments also will be insignificant, even if the assumption of complete mixing throughout the water column is incorrect. If the daily volume of resuspended sediment were to mix with only 1 percent of the volume of water passing the bridge during a given flood or ebb tide, the BOD_5 exerted daily on that small volume of water would still be only 9.3×10^{-3} mg/L.

Table 4.--Biochemical oxygen demand (BOD) of bottom sediments and raw-water samples from Jamaica Bay, N.Y., March 18, 1984.

[Site locations are shown in fig. 3.]

Site no.	Sample type[1]	Instantaneous (mg/L)	Daily BOD (mg/L) Day 1	Day 2	Day 3	Day 4	Day 5	Estimated BOD_5[2] (mg/L)	(mg/g)	(mg/ft^3)
	Raw water	0.1	1.2	2.2	3.5	4.6	5.2	--	--	--
1	SW	1.6	5.2	6.8	8.0	8.5	8.6	10.2		
	S	1.5	4.0	4.6	4.5	3.9	3.4	5.0	1.1	59,500
2	SW	1.0	4.1	6.1	7.3	7.9	8.1	9.5		
	S	.9	2.9	3.9	3.8	3.3	2.9	4.3	.9	51,100
3	SW	1.7	4.3	6.4	7.8	8.6	9.1	9.9		
	S	1.6	3.1	4.2	4.3	4.0	3.9	4.7	1.0	55,900
4	SW	1.7	4.7	6.3	7.5	8.1	8.5	9.5		
	S	1.6	3.5	4.1	4.0	3.5	3.3	4.3	.9	51,100
5	SW	2.0	5.1	6.6	7.8	8.4	8.6	9.8		
	S	1.9	3.9	4.2	4.3	3.8	3.8	4.6	1.0	54,700
6	SW	1.4	4.0	5.7	7.0	7.6	7.9	9.0		
	S	1.3	2.8	3.5	3.5	3.0	2.7	3.8	.8	45,200
7	SW	2.0	5.4	7.3	8.7	9.0	9.1	11.1		
	S	1.9	4.3	5.1	5.2	4.4	3.9	5.9	1.2	70,200
8	SW	1.9	3.8	5.2	6.6	2.6	8.3	8.3		
	S	1.8	2.6	3.0	3.1	3.0	3.1	3.1	.7	36,900

[1] SW = sediment-and-water mixture.
S = sediment only (BOD of sediment-and-water mixture minus BOD of raw water).

[2] BOD5 = estimated 5-day biochemical oxygen demend

The BOD_5 exerted as a result of bridge construction can also be compared to the daily loadings of BOD_5 from sewage-treatment plants and other discharges to the bay. Feuerstein (1976, p. 97) estimated that the Jamaica water-pollution-control facility discharges 5.5 million pounds of BOD_5 per year to Grassy Bay, which converts to a daily loading of 6,847 kg/d of BOD_5. This value is 4 orders of magnitude greater than the 529 g of BOD_5 that would be released daily during bridge construction.

The above data indicate that the oxygen demand of the sediments in the vicinity of the North Channel Bridge area is relatively low and that the oxygen demand exerted on the water column as a result of the bridge replacement will be insignificant in relation to present background levels.

Metals in Bottom Sediments

Results of the bottom-sediment metals analysis (table 5) show a wide variation in the metals concentration among the sampling sites near the North Channel bridge. Zinc concentrations ranged between 12 and 340 μg/g; lead ranged between 10 and 150 μg/g, and copper ranged between 4 and 85 μg/g. Within individual samples, however, the metal concentrations tended to be consistent; for example, samples with a high concentration of an individual metal (such as sample 5 in table 5) tended to have a high concentration of all metals, and samples with a low concentration of an individual metal (such as sample 8) tended to have a low concentration of all metals.

The variability in chemical quality of the bottom sediment is probably due to several interrelated factors that control the deposition of fine-sized particles. Raymondetta and Harris (1978) and other investigators have found that metals and toxic organic compounds in bottom sediments are commonly associated with the fine organic materials in bottom sediments. These fine materials will settle most readily in areas of low energy, which are also favorable for the deposition of other fine-sized particles. This may explain why shallow areas affected by high-energy wave action, such as at sites 6 and 8 (fig. 3), had a high percentage of sand and a low metals concentration, while the deeper, more protected, low-energy areas under the bridge, such as sites 4 and 5, had a high percentage of fine-sized particles and a much higher metals concentration.

This relationship between particle size, metals concentration, and energy conditions will be important in the transport and redeposition of sediments suspended during bridge construction because, upon suspension, a disproportionate amount of the metals is likely to be carried by the fine-sized particles and redeposited in deep, low-energy areas.

The chemical quality of sediments at the North Channel bridge can be compared with that of other sediments within the bay through analyses of the statistical characteristics of metals-concentration data collected elsewhere in the bay by other investigators. Table 6 contains this information and also a classification of bottom sediments by Prater and Hoke (1980) that designates sediment as nonpolluted, moderately polluted, or heavily polluted. The data in this table indicate that the bottom material in the vicinity of North Channel bridge is of fair to good chemical quality.

The mean metals concentrations of the bottom-sediment samples collected by the U.S. Geological Survey in the vicinity of the bridge are uniformly lower

Table 5.--Metals concentration, particle-size distribution of sediment samples, and field description of bottom sediment from Jamaica Bay, N.Y.

[Site locations are shown in fig. 3. Analyses by U.S. Geological Survey.]

A. METALS CONCENTRATION AND PARTICLE SIZE

Site	Metal concentration (μg/g)									Particle size (percent)			Water depth (ft)
	Arsenic	Barium	Cadmium	Chromium	Copper	Lead	Mercury	Selenium	Zinc	Sand	Silt	Clay	
1	3	10	2	20	27	50	0.31	<1	87	77	19	3	7
2	2	<10	1	10	7	10	<.01	<1	32	61	36	3	10
3	2	10	2	30	40	60	.23	<1	120	80	15	5	16
4	3	40	2	20	39	90	.42	<1	170	49	46	6	10
5	6	80	3	30	85	150	.78	<1	340	37	63	0	10
6	1	<10	<1	7	11	10	.04	<1	46	93	7	0	6
7	3	20	3	10	31	60	.56	<1	99	68	31	1	10
8	1	<10	<1	7	4	40	<.01	<1	12	84	14	2	8

B. FIELD DESCRIPTION OF SEDIMENT

Site	
1	Dark-gray sandy mud overlain by brown sand with shell fragments, moderate hydrogen sulfide odor.
2	Gray mud overlain by coarse brown sand with fine shell fragments, slight hydrogen sulfide odor.
3	Very hard, shallow sample, brown sand with many large shells, live clams.
4	Cohesive gray mud overlain by shell fragments, hydrogen sulfide odor.
5	Very cohesive black mud with very fine shell fragments, strong hydrogen sulfide odor.
6	Black silty sand with oyster shells, hydrogen sulfide odor.
7	Dark-brown cohesive sandy mud with oyster shells, hydrogen sulfide odor.
8	Light-brown clean sand with roots, grasses, and live clams.

than in samples collected throughout the bay by Ramondetta and Harris in 1972 (table 6). However, the mean of the Ramondetta-Harris data is skewed by the high metals concentrations of samples from Grassy Bay and Head-of-Bay. For example, the mean lead concentration of the five samples taken in Grassy Bay by Ramondetta and Harris was 275 µg/g, whereas that of samples collected by the U.S. Geological Survey at the North Channel bridge was 60 µg/g. Therefore, the metals concentration of bottom sediment in the vicinity of the bridge is generally less than the average metals concentration of sediments throughout the bay and is considerably less than that of sediments in heavily polluted areas of the bay as measured by Ramondetta and Harris in 1972.

With local exceptions, bottom sediments west of the bridge have lower metals concentrations than those east of it. The local exceptions are near outlets of combined sewage overflows and sewage-treatment plants west of North Channel (Ramondetta and Harris, 1978, p. 147). As shown in table 6, the mean metals concentration of samples collected from the western part of the bay along North Channel and Pumpkin Patch Channel by Franz and Harris (1983) are considerably lower than those obtained throughout the bay by Ramondetta and Harris in 1972.

The data collected by the U.S. Geological Survey indicate that the metals concentration of the bottom sediment in the vicinity of the North Channel bridge is within the general range found in the bottom material to the west of the bridge, although some metals are slightly higher. As seen in table 6, the mean concentration of the metals measured by the Geological Survey at the bridge is within the minimum-maximum range measured by Franz and Harris (1983) in the western part of Jamaica Bay, and most are within 1 standard deviation of the mean of these same metals. The mean values of zinc and mercury measured by the Geological Survey at the bridge are less than those measured by Franz and Harris in the western part of Jamaica Bay, whereas the mean values for cadmium, copper, and selenium are greater.

According to the criteria developed by Prater and Hoke (1980), the mean concentrations of arsenic, barium, lead, and zinc at the bridge are in the "moderately polluted" range, but the mean values for chromium, copper, and mercury are in the "nonpolluted" range. None of the metals at the bridge are in the "heavily polluted" range. However, from the variability in the bioaccumulation of metals from sediments, these ranges seem somewhat arbitrarily assigned. Hirsh and others (1978, p. 4) found that

> Investigations of the availability of sediment-sorbed heavy metals to organisms showed bioaccmulation of metals to be minimal and highly variable. For most metals studied, uptake by organisms was not evident. Some researchers felt that relatively few isolated instances of heavy metals accumulation from sediments could be interpreted as ecologically meaningful in terms of direct toxicity to the organisms and its predators, or as a pathway for the entrance of sediment-sorbed heavy metals into aquatic food chains.

In a review of the available literature, Neff and others (1978) found that because several heavy metals are essential micronutrients to benthic invertebrates, they are actively accumulated from even very dilute solution, but accumulation of heavy metals from sediment by invertebrates (when it can be demonstrated) is generally several orders of magnitude less efficient than accumulation from aqueous solution. Furthermore, correlation between metal concentration in the sediment and in the associated benthic invertebrates varies from one sediment type to another, but where such correlation is evident, it may be due to a source of metals common to both the sediment and biota, rather than transfer of metals from sediment to the biota. Hirsch and others (1978, p. 35) went on to conclude that the release of heavy metals from sediment and their uptake into organism tissue is the exception rather than the rule and found little or no correlation between heavy-metals concentration in bulk samples and the uptake of the metals by organisms.

Table 6.--Statistical summary of metals concentration in bottom sediment of Jamaica Bay, N.Y.

[Concentrations are in micrograms per gram.]

Constituent	Number of samples	North Channel (U.S. Geological Survey) Minimum	Maximum	Mean	Median	Std. dev.	Jamaica Bay (Ramondetta and Harris, 1972) Mean	Std. dev.
Arsenic	8	<1	6	[2]3	2	2	--	--
Barium	8	<10	80	20	10	25	--	--
Cadmium	8	<1	3	2	2	1	3.15	3.32
Chromium	8	7	30	17	15	10	--	--
Copper	8	4	85	31	30	26	85.7	117
Lead	8	10	150	60	55	45	115	121
Mercury	8	<.01	.78	.30	.27	.28	--	--
Selenium	8	<1	10	2	1	3	--	--
Zinc	8	12	340	110	93	105	196	256

Constituent	Classification of chemical quality of sediments (Prater and Hoke, 1980) Non-polluted areas	Moderately polluted areas	Heavily polluted areas	Western Jamaica Bay[1] (Franz and Harris, April & November, 1982) Minimum Apr.	Minimum Nov.	Maximum Apr.	Maximum Nov.	Mean Apr.	Mean Nov.	Std. dev. Apr.	Std. dev. Nov.
Arsenic	<3	3-8	>8	--	--	--	--	--	--	--	--
Barium	<20	20-60	>60	--	--	--	--	--	--	--	--
Cadmium	--	--	>6	0.57	.23	1.6	2.7	0.92	0.96	0.37	0.80
Chromium	<25	25-75	>75								
Copper	<25	25-50	>50	4.4	3.9	41	89	15	26	12	32
Lead	<40	40-60	>60								
Mercury	<1.0	--	>1.0	.06	--	2.8	--	.63	--	.82	--
Selenium	--	--	--	.40	.64	1.1	2.0	.67	1.23	.27	.99
Zinc	<90	90-200	>200	62	44	545	187	165	88	154	57

[1] Samples collected April and November 1982.
[2] In calculating the means of the U.S.Geological Survey data, "less than" (<) values were assigned their high limit values. This convention may result in artificially inflated mean values.

In summary, the bottom sediments in the vicinity of the North Channel bridge generally had lower mean metals concentrations in 1984 than those measured elsewhere throughout the bay in 1972. The 1984 metals concentrations near the bridge were much lower than those in Grassy Bay and were similar to those in the western part of the bay. As expected, the metals appear to be associated with fine-sized particles and are likely to be transported with these particles after suspension. Because the finest particles and the associated metals will be transported furthest from the bridge, they will probably become widely dispersed and are thus unlikely to settle in large quantities in any given area. Also, metals associated with fine-sized material, both organic and inorganic, tend to be tightly bound and, therefore, will be generally unavailable for biological uptake.

Organic Compounds in Bottom Sediments

Results of the analysis for organic compounds (table 7) indicate several organic compounds in trace concentrations in the bottom material in the vicinity of the North Channel Bridge. PCB's, which had concentrations ranging from 2 to 20 µg/kg, were found in more samples (5) than any other organic compound. Fulk and others (1975) also found PCB's to be the most common of the organic compounds they analyzed for in bottom material from five different locations throughout the United States. The concentrations of PCB's in the vicinity of the bridge as measured by the Geological Survey are considered very low for estuarine bottom sediments in developed areas (N. I. Rubinstein, U.S. Environmental Protection Agency, and R. J. Huggett, Virginia Institute of Marine Sciences, oral commun., June 1984). For example, bottom-material samples collected by Rubinstein and others (1982) from four sites in the New York Harbor, about 15 mi west of Jamaica Bay, had PCB concentrations between 460 and 7,280 µg/kg. The PCB concentrations in the vicinity of the bridge are surprisingly low, considering the number of possible sources discharging to Jamaica Bay and the fact that Feuerstein (1976) reported significant amounts of PCB's, DDT, DDD, and DDE in water from the North Channel area of Jamaica Bay. Feuerstein (1976) also reported PCB concentrations in bottom-material samples from eight sites throughout the bay that ranged between 26 µg/kg in the North Channel area to 1,835 µg/kg in Grassy Bay. These concentrations are as much as 2 orders of magnitude greater than those measured by the Geological Survey in the vicinity of the North Channel bridge.

Feuerstein (1976) also reported dieldrin in the bottom material in concentrations of 1 µg/kg, 19 µg/kg, and 65 µg/kg at North Channel, Head-of-Bay, and Grassy Bay, respectively; in contrast, the Geological Survey found dieldrin in measurable quantites in only one sample--0.7 µg/kg at site 3.

The highest concentration of any single organic compound measured in 1984 at the North Channel bridge was 28 µg/kg of chlordane at site 3. Because chlordane has been commonly used for termite extermination in urban areas, its presence in the bottom sediment of Jamaica Bay is not surprising. Site 3 (fig. 3) was the only location in which measurable quantities of chlordane, DDT, and dieldrin were found, however, and was one of only two sites with measurable DDD. As noted previously, the sample from site 3 was the only one collected by the Ponar clamshell sampler and was therefore the only sample consisting totally of shallow (3- to 4-inch depth) bottom sediment. This indicates either that site 3 is a localized "hot spot" of chlordane and other chlorinated pesticides or that the chlorinated pesticides are concentrated in the surface sediments and were largely missed at the seven sites sampled with the piston core sampler.

Table 7.--Concentration of selected organic compounds in bottom sediments of Jamaica Bay.

[Concentrations are in µg/kg. Dashes indicate concentration was less than the detection limit. Site locations are shown in fig. 3. Analysis by U.S. Geological Survey.]

Constituent	Sampling location: Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Detection limit	Present in number of samples	mean[1]
Aldrin	--	--	--	--	--	--	--	--	0.1	0	<0.1
Chlordane	--	--	28	--	--	--	--	--	.1	1	4.4
DDD	--	--	5.4	--	--	--	3.2	--	.1	2	1.2
DDE	--	--	--	0.8	0.7	7.9	--	--	.1	3	1.2
DDT	--	--	1.3	--	--	--	--	--	.1	1	.3
Diazinon	--	--	--	--	--	--	--	--	.1	0	<.1
Dieldrin	--	--	0.7	--	--	--	--	--	.1	1	.2
Endosulfon	--	--	--	--	--	--	--	--	.1	0	<.1
Endrin	--	--	--	--	--	--	--	--	.1	0	<.1
Ethion	--	--	--	--	--	--	--	--	.1	0	<.1
Heptachlor epoxide	--	--	--	--	--	--	--	--	.1	0	<.1
Heptachlor	0.2	--	--	.2	--	.3	--	--	.1	3	.2
Lindane	--	--	--	--	--	--	--	--	.1	0	<.1
Malathion	--	--	--	--	--	--	--	--	.1	0	<.1
Methoxychlor	--	--	--	--	--	--	--	--	.1	0	<.1
Methyl trithion	--	--	--	--	--	--	--	--	.1	0	<.1
Methylparathion	--	--	--	--	--	--	--	--	.1	0	<.1
Mirex	--	--	--	--	--	--	--	--	.1	0	<.1
Gross PCB	2	--	--	6	8	9	20	--	.1	5	6
Gross PCN	--	--	--	--	--	--	--	--	.1	0	<.1
Parathion	--	--	--	--	--	--	--	--	.1	0	<.1
Perthane	--	--	--	--	--	--	--	--	.1	0	<.1
Toxaphene	--	--	--	--	--	--	--	--	10	0	<10
Trithion	--	--	--	--	--	--	--	--	.1	0	<.1

[1] In calculating means, values less than the detection limit were given the value of the detection limit.

The significance of the organic compound concentrations in the vicinity of the North Channel bridge is difficult to interpret because data on organic compounds elsewhere within the bay are scant. However, the information available (Feuerstein, 1976) indicates that the concentrations of PCB's and dieldrin in the bottom sediments in the bridge vicinity are very low in relation to those elsewhere within the bay, even west of the bridge. In addition, these compounds generally do not readily desorb from bottom sediments and therefore provide only limited availability to benthic organisms (Hirsch and others, 1978, p. 31).

Metals and Nutrient Exchange

The exchange of metals and nutrients from or to the bottom-material samples was calculated by subtracting the concentration of the constituents in solution in the raw water from the concentration of the constituents remaining in solution in the sediment-water mixture after the 24-hour mixing period. A positive difference represents exchange from the sediment to the water column, and a negative difference represents exchange from the water column to the sediments. The concentration of constituents in solution in the raw water samples and in the mixture of sediment and water, and the differences between them, are listed in table 8.

As seen in table 8, the exchange characteristics of individual metals from the bottom material differ widely. A given bottom-sediment sample will adsorb some metals and release others, and an individual metal will adsorb to some sediment samples and be released from others. In addition, no relationship is evident between the metals concentration of the bottom-sediment sample (table 5) and the amount of metals exchanged from the sample to the water (table 8). Furthermore, a sample with a low metal concentration may release more of the metal than a sample with a high metal concentration. It is likely that the speciation of the metals in the bottom sediment and the composition and exchange capacity of the bottom sediments, as well as other physiochemical factors, rather than the metals content alone, control the exchange of metal from the sediments. If the metals are largely complexed by organic material, the metals concentration of a sample may be high, but the exchange from the sample will be low.

As seen in table 8, the exchange characteristics of nutrients were more consistent than those of metals. In nearly all samples, ammonia and kjeldahl (ammonia plus organic) nitrogen were released from the bottom material, and phosphorus was adsorbed by the sediment. Nitrate and nitrite nitrogen were below the detection levels in all samples. As would be expected for the reducing environment of bottom sediments, most of the nitrogen is in the reduced form.

The concentrations of the constituents exchanged to or from each sample were averaged and converted to a per-volume-of-sediment basis. Because 300 cm^3 of sediment and 2,100 mL of raw water were used in the exchange experiment, an average exchange concentration of 1 mg/L converts to an average exchange of 198 mg/ft^3 of sediment. The average exchange concentrations and average exchange amounts of each constituent are included in table 8.

The results of the exchange experiment indicate that the amounts of metals and nutrients released from the bottom material to the water column are negligible. For example, if 10 ft^3 of bottom material is released each day to the

Table 8.--Concentration of dissolved constituents of raw water and in mixtures of sediment and water calculation of metal and nutrient exchange.

(Site locations are shown in fig. 3.)

Source or site number	Barium (µg/L)	Cadmium (µg/L)	Chromium (µg/L)	Copper (µg/L)	Lead (µg/L)	Mercury (µg/L)	Selenium (µg/L)	Zinc (µg/L)	Calcium (mg/L)	NO_2 + NO_3 as N (mg/L)	NH_4 as N (mg/L)	Kjel-dahl-as N (mg/L)	Dis-solved PO4 as P (mg/L)	Dis-solved P (mg/L)
Raw water 1	100	<1	30	4	9	0.7	<1	20	300	<0.1	1.1	1.6	0.10	0.11
Raw water 2	<100	<1	40	6	10	1.1	<1	20	300	<.1	1.1	1.7	.10	.11
Average raw water	100	<1	35	5	9	.9	<1	20	300	<.1	1.1	1.7	.10	.11
1 measured	100	<1	30	18	6	1.4	<1	30	250	<.1	5.2	12	.08	.16
exchange	0	0	-5	+13	-3	+.5	0	+10	-50	0	+4.1	+10.3	-.02	+.05
2 measured	200	<1	30	21	10	1.3	<1	20	250	.1	.63	2.8	.08	<.01
exchange	+100	0	-5	+16	+1	+.4	0	0	-50	0	-.5	+1.1	-.02	-.10
3 measured	200	<1	30	2	7	.2	<1	30	290	<.1	1.4	1.8	.01	.03
exchange	+100	0	-5	-3	-2	-.7	0	+10	-10	0	+.3	+.1	-.09	-.08
4 measured	100	<1	30	12	5	1.0	<1	20	280	.1	10	11	.33	.03
exchange	0	0	-5	+7	-4	+.1	0	0	-20	0	+8.9	+9.3	+.23	-.08
5 measured	100	<1	30	17	8	.5	<1	20	320	<.1	19	24	.29	.36
exchange	0	0	-5	+12	-1	-.4	0	0	+20	0	+17.9	+22.3	+.19	+.25
6 measured	<100	<1	30	9	6	.3	<1	20	280	<.1	1.7	1.8	<.01	.03
exchange	0	0	-5	+4	-3	-.6	0	0	-20	0	+.6	+.1	-.09	-.08
7 measured	100	<1	40	9	3	.2	<1	30	330	<.1	5.1	5.2	.01	.04
exchange	0	0	+5	+4	-6	-.7	0	+10	+30	0	+4.0	+3.5	-.09	-.07
8 measured	100	<1	30	15	33	--	<1	50	240	<.1	4.3	5.5	<.01	.04
exchange	0	0	-5	+10	+22	--	0	+30	-60	0	+3.2	+3.8	-.09	-.07
Average measured	125	<1	31	13	10	.7	<1	28	280	<.1	5.9	8.0	.10	.09
Average exchange	+25	0	-4	+8	+1	-.2	0	+8	-20	0	4.8	6.3	.00	-.02
mg/ft^3	4.95	0	-.79	1.58	.20	-.04	0	1.58	-3960	0	950	1247	0	4

water column as a result of bridge replacement, 49.5 mg of barium and 9,491 mg of ammonia will be released to the water column on a given day. If approximately 2 x 10^8 ft^3 or 5.7 x 10^9 L of water passes the bridge during a given flood or ebb tide, and complete mixing occurs over the two tidal cycles that day, the increase in barium concentration in the water column each day amounts to 8.7 x 10^{-9} mg/L, and the increase in ammonia is 1.7 x 10^{-6} mg/L--both of which are several orders of magnitude below the detection limits. Even if the daily load of these constituents were to mix with only 1 percent of the volume of water in a given flood tide, the additional concentration in that volume of water would still be undetectable.

The amount of nutrients released through bridge replacement would be minimal in relation to the daily load of nutrients discharged from sewage-treatment plants and other nutrient sources to the bay. Feuerstein (1976, p. 97) estimated that the upgraded Jamaica water-pollution-control facility discharges 7.89 million pounds of total nitrogen per year and 2.34 million pounds of total phosphorous to Grassy Bay per year. This converts to a daily loading of 9,825 kg of total nitrogen and 2,914 kg total phosphorus. In the same study, the daily loading from all sources to Jamaica Bay was estimated to be 34,993 kg of total nitrogen and 7,559 kg of total phosphorus, both of which are 6 to 7 orders of magnitude greater than the 12.3 g of kjeldahl nitrogen that would be released from the suspended bottom sediments each day during bridge replacement. The dissolved phosphorus in the water column should actually decrease as a result of adsorbtion to the suspended sediments.

Thus, the results of this analysis indicate that the anticipated release of metals and nutrients to the water column from the suspended sediments will be virtually undetectable and will have a negligible effect on the quality of water in the bay.

Settling Velocity

The settling-velocity data from the bottom-sediment samples (table 9) are in grams per time interval and as the percentage of each sample that falls a distance of 1 m under nonturbulent conditions within that interval. For example, 82.5 percent of sample 1 fell 1 m in less than 4.5 min, an additional 11.7 percent fell 1 m in less than 15 min, and 3 percent would not fall 1 m in 4,000 min. The average settling times for all samples are also listed in table 9.

The data in table 9 indicate that most of the bottom sediment that becomes resuspended during bridge replacement will settle relatively quickly. On the average, 75 percent of the bottom sediment will fall 1 m or more in less than 4.5 min; between 56 and 94 percent of the bottom sediment in individual samples settled at that rate. The particle sizes that settle within this time consist mostly of fine sand and larger particles. An additional 17 percent of the bottom sediment, consisting mostly of silt-size particles, will complete the 1-m fall within the next 10.5 min. Thus, a total of 92 percent of the bottom material will settle a distance of 1 m in less than 15 min. Between 85 and 96 percent of the bottom sediment settled at that rate in individual samples. An average of 1.4 percent of the bottom material (clay-sized particles) did not fall the 1-m distance within 4,000 min, slightly more than 2 1/2 days.

The settling velocities were measured in the laboratory under nonturbulent conditions and therefore overestimate the settling velocities that would occur in the water column of Jamaica Bay. Turbulence due to current velocity, bottom shear, and wave action that occur within Jamaica Bay will keep particles in suspension longer than the nonturbulent conditions of the laboratory, particularly the smaller particles. However, the settling rate of the sand and possibly the larger silt-sized fractions, which together form the majority of the bottom sediments, will probably not be greatly increased because the average flow velocity measured at the bridge during ebb tide did not exceed 1.36 ft/s.

Table 9.--Settling-velocity data, as weight in grams and percentage of total bottom sediment settling 1 meter during given time period.

[Dashes indicate that no detectable amount of sediment fell during the given time period. Site locations are shown in fig. 3.]

	Time interval, in minutes									
Site	< 4.5	4.5-15	15-40	40-80	80-200	200-400	400-700	700-1500	1500-4000	> 4000
1 grams	6.49	0.92	0.19	0.06	0.03	0.02	0.04	0.02	--	0.24
percent	82.5	11.7	2.5	.8	.4	.2	.3	.02	--	3
2 grams	4.83	1.55	.46	.07	.05	.09	.09	.06	0.005	.12
percent	66.1	21.2	6.3	.9	.6	1.2	1.2	.8	.06	1.5
3 grams	6.81	.43	.06	.02	.02	.02	.07	.002	.04	.27
percent	88	5.6	.8	.2	.2	.3	.8	.02	.6	3.4
4 grams	4.93	2.22	.69	.07	.004	.02	.03	.05	.08	.30
percent	58.7	26.4	8.2	.8	.05	.26	.36	.6	.92	3.5
5 grams	2.57	1.89	.17	--	--	--	--	--	--	--
percent	55.5	40.9	3.6	--	--	--	--	--	--	--
6 grams	7.26	.22	.16	.07	.04	--	--	--	--	--
percent	93.7	2.9	2.0	.87	.48	--	--	--	--	--
7 grams	4.54	1.06	.34	.08	.10	.006	.009	.02	.04	--
percent	73.2	17	5.5	1.3	1.6	.09	.16	.35	.67	--
8 grams	7.72	.76	.25	.07	.02	.13	--	--	--	--
percent	86.2	8.5	2.8	.82	.21	1.4	--	--	--	--
Average percent	75.5	16.8	4.0	.7	.4	.3	.4	.2	.3	1.4

Sediment Transport

A rigorous analysis of sediment transport was considered unnecessary because the levels of contamination in the bottom sediments at the North Channel Bridge were low and because the bottom sediments contain a large proportion of sand.

Therefore only a simple, semiquantitative analysis of sediment transport was conducted, the purpose of which was to identify the area to the west of the North Channel bridge in which bottom material that becomes suspended through bridge-construction activities is likely to be deposited. Sediment transport to the east of the bridge was not considered important because the bottom material in that direction is probably equal or inferior in chemical quality to that of the resuspended sediment.

The assumptions made in this analysis were that the mean velocity during an ebb tide in North Channel and Pumpkin Patch Channel is the same as the 0.44-ft/s average ebb-tide velocity measured in the spring of 1984 at the bridge. The average velocity in North Channel is probably less than at the bridge as a result of its much greater cross-sectional area. The difference between average velocity within Pumpkin Patch Channel and the North Channel is unknown. A second assumption was that, during ebb tide, the resuspended bottom material would travel mainly through the channels (Leendertse and Gritton, 1971, p. 69) under nonturbulent conditions and that the average settling depth would be the mean channel depth--2.5 m for Pumpkin Patch Channel and 4.5 m for Broad Channel. It was further assumed that the sediment will be suspended randomly throughout the tidal cycle with equal likelihood of initially traveling either east or west from the bridge site. Only westward transport is considered here, however.

From these assumptions and the average settling-velocity times given in table 9, the average settling distances of selected percentages of sediment was calculated for an average ebb tide. As indicated in table 10, 75 percent of the suspended bottom sediments, on the average, will settle within 610 ft of the bridge, and 92 percent will settle within 1,800 ft of the bridge. The lines of equal settling distance for given time periods and the corresponding percentages of bottom sediments that have settled are plotted in figure 5. The 96.7-percent line, which corresponds to a 6-hour traveltime, is the maximum distance traveled from the bridge site during an average ebb tide. Its position indicates that the vast majority of suspended bottom sediments can be expected to settle in North Channel and Pumpkin Patch Channel within the first ebb tide.

Table 10.--Average distance from North Channel bridge in which a given percentage of suspended bottom sediments will settle.

[Locations shown in fig. 5.]

Location	Percentage of material deposited	Average settling time (min)	Average distance from bridge (ft)
North Channel	75	23	610
	92	68	1800
	96	180	4750
	96.7	360	9500
Pumpkin Patch Channel	75	13	340
	92	38	1000
	96	100	2640
	96.7	200	5280

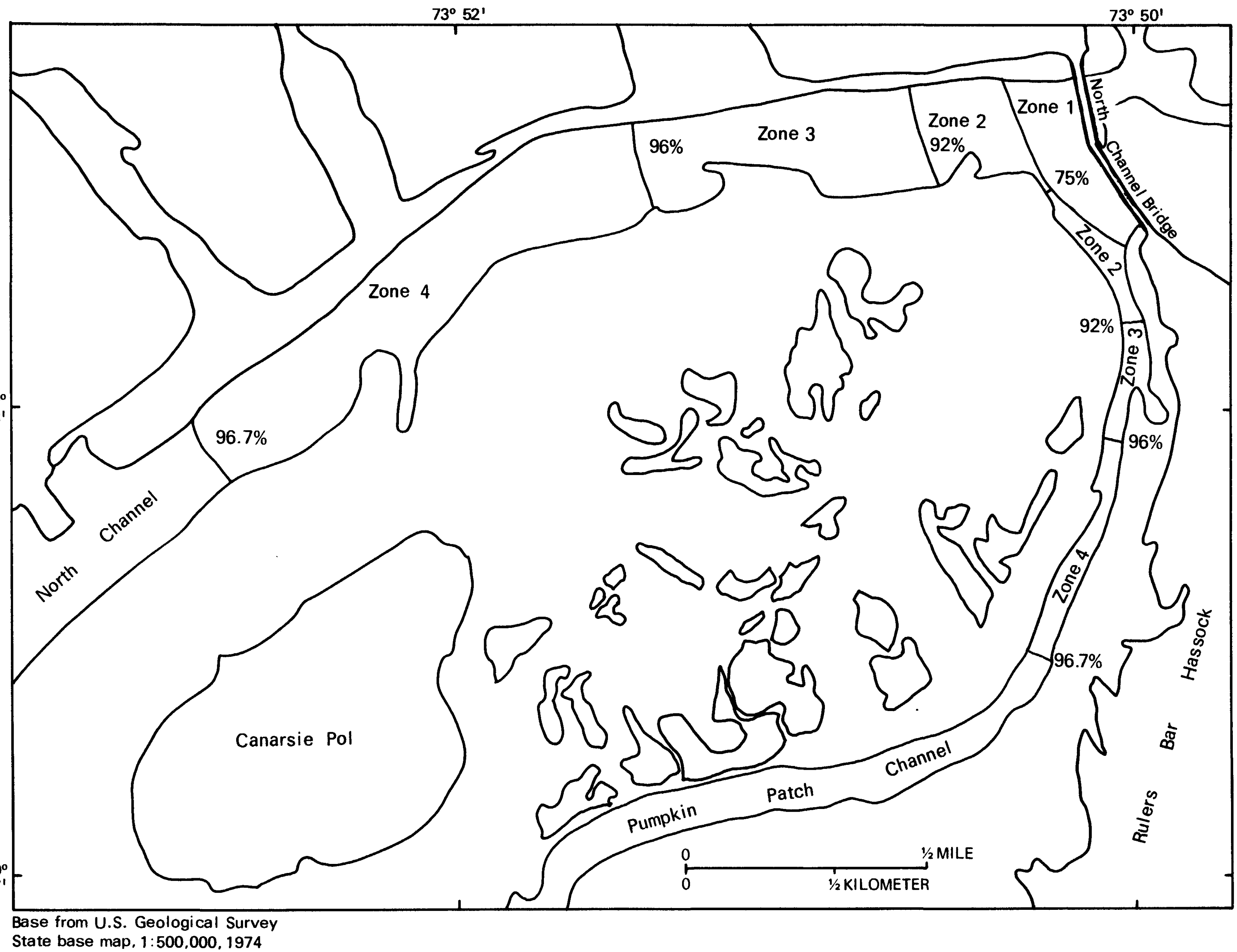

Figure 5.--Percentage of suspended bottom sediments deposited in North Channel and Pumpkin Patch Channel during an average ebb tide.

For comparison with these estimates, figures 6A and 6B show results of the Rand Corporation's Jamaica Bay Model (Leendertse and Gritton, 1971) of the coliform distribution resulting from discharge at the Spring Creek combined sewer outfall at high and low tide. The input conditions used for this model run were typical average dry-weather flow and coliform density. Although tidal discharges may vary considerably on a daily basis and cause changes in the circulation pattern, figure 6 represents the typical circulation pattern within the North Channel area as indicated by coliform distribution after a typical flood and ebb tide.

Because the Spring Creek outfall enters Jamaica Bay 0.8 mi west of the North Channel bridge (fig. 6), the discharged coliform bacteria will be follow a circulation pattern similar to that of the sediment suspended through bridge construction. Thus, the distribution of suspended sediments through an ebb-tide cycle will be similar to the coliform distribution depicted in figure 6, with minor differences. (Specifically, the decay rate of the bacteria is not comparable to the settling rate of the sediments; the location of the coliform-discharge point exaggerates the transport to the west, and, as previously mentioned, daily changes in discharge will alter the circulation pattern.) Nevertheless, figure 6 indicates the probable western limit of sediment transport during a single ebb tide. As the settling-velocity data (table 10) indicate, the vast majority of suspended bottom sediment will settle within this area. As seen in figures 5 and 6, the areas within which 96.7 percent of the bottom material will be redeposited in both the North Channel and Pumpkin Patch Channel lies within these western limits as determined by the Rand model.

During the succeeding flood tide, the fine-grained bottom sediments remaining in suspension in Pumpkin Patch Channel and North Channel will be pushed back toward the bridge through the channels and out onto the shallow flat areas adjacent to the channels, where they will remain until the following ebb tide. While on the flats, the fine-sized particles in suspension may settle out unless wave action in these shallow waters produces sufficient turbulence to keep them in suspension until the ebb tide, when once again they will be removed to the deep channels. It is likely that these fine particles, while becoming dispersed and gradually transported to the west toward the outlet to the ocean, will eventually settle out in the deep and relatively quiescent dredged channels.

Sediment Deposition

The prevailing energy conditions that have largely determined the present composition of the bay bottom are also likely to determine the location of fine-sized particle deposition. The sandy areas within the bay, which are likely to be relatively uncontaminated (similar to sites 6 and 8), have formed wherever the water's energy is high enough to prevent the deposition of fine particles and their associated contaminants. (The fine-sized particles are likely to be deposited in low-energy areas, which are already occupied by fine-sized particles that may already be contaminated, such as sites 4 and 5). As Ramondetta and Harris (1978) found, metal concentrations in the bottom sediments of the North Channel area reflect current velocities--the metal concentrations were high in the wide channel areas that have weak currents and were low in the narrow channel areas that have strong currents.

Because the ambient energy at a given location largely determines the potential for fine-sized particle deposition, the depth of sedimentation at any given

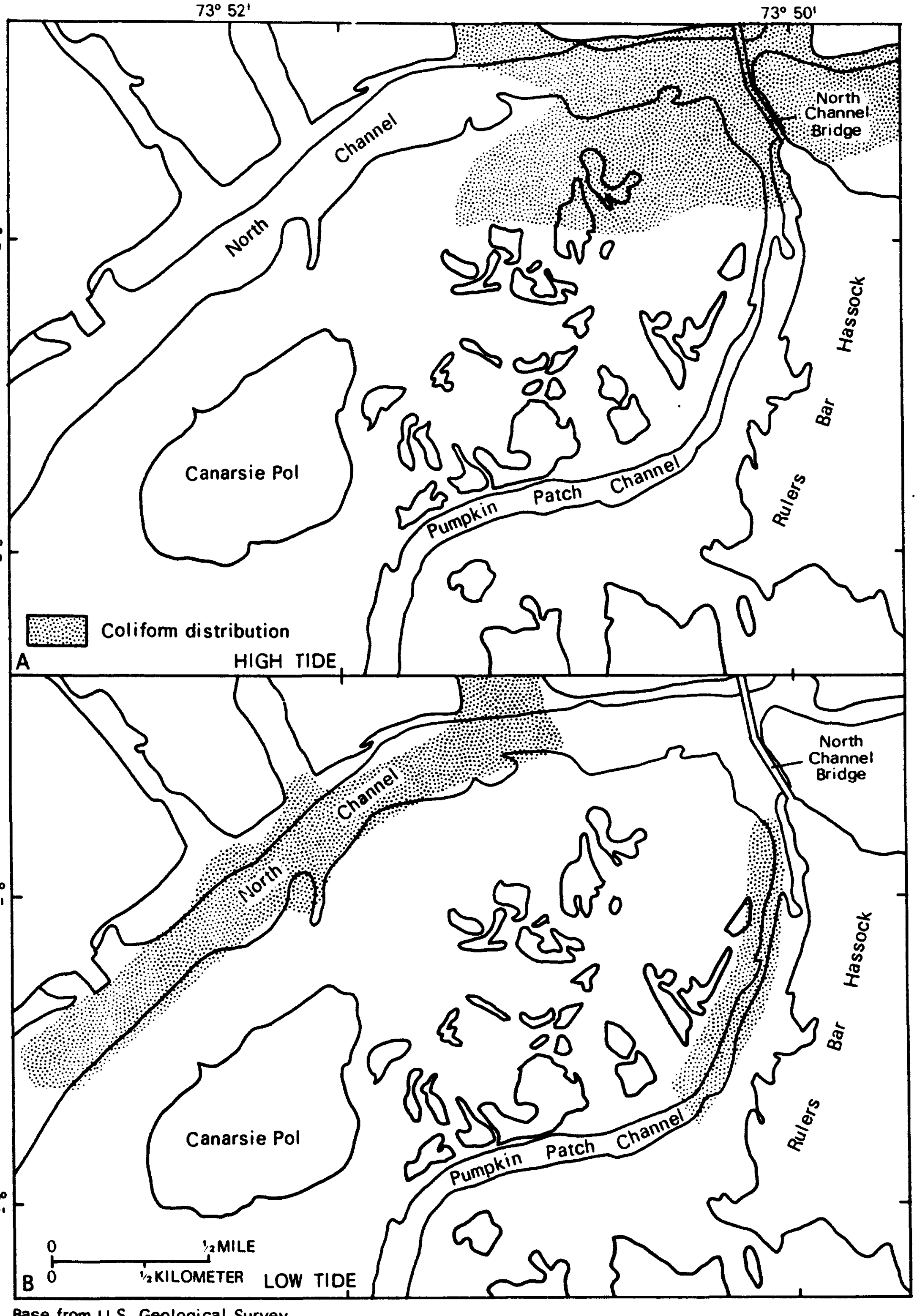

Figure 6.--Computer-generated coliform distribution from Spring Creek sewage outfall: A. At high tide. B. At low tide. (Model data from Rand Corporation, Jamaica Bay Model; illustrations modified from Leenderste and Gritton, 1971, p. 65.)

location is difficult to predict without extensive sediment-trap data collection in the field. However, a simple analysis of deposition based on the settling-velocity and current-velocity data collected during this study may be sufficient to calculate the approximate magnitude of deposition in various areas.

Four zones that correspond to the lines of 75-, 92-, 96-, and 96.7-percent deposition are shown in figure 5. Zone 1 is the area in which 75 percent of the suspended bottom sediments will be deposited during an average ebb tide; zone 2 is the area in which an additional 17 percent of the suspended bottom sediments will be deposited, and so on. The total depth of sediment deposition within each zone was calculated from the assumptions made earlier to describe sediment transport and the further assumptions that (a) only half of the 2,145 ft^3 of bottom sediments suspended by bridge-construction activities will be carried westward immediately after suspension, (b) 80 percent of the sediment will travel through North Channel and 20 percent will travel through Pumpkin Patch Channel, and (c) the sediment will be deposited evenly within each zone.

From these assumptions, the calculated depth of sediment deposition ranged from 1.1×10^{-5} inches in zone 4 to 6.0×10^{-3} inches in zone 1 of North Channel (table 11). These values, which seem extremely small, are based on the assumption that sediment will be deposited evenly throughout each zone. Actually deposition is unlikely to be evenly distributed owing to local differences in channel depth and current velocity. Yet, even if deposition occurs only in 5 percent of the area available in a given zone, the greatest thickness that would accumulate anywhere would be 0.12 inch in zone 1 of North Channel.

The 3.3 percent of the sediment not accounted for in this analysis consists of the finest particles. This fraction, which probably carries a disproportionate amount of contaminants, is unlikely to be deposited during the first ebb tide and will probably become widely dispersed throughout succeeding tidal cycles. Thus, this relatively small volume of sediment, about 34 ft^3, will settle over a wide area and therefore accumulate to only a very small thickness.

Table 11.--Size of deposition zones in North Channel and Pumpkin Patch Channel and the calculated volume and depth of sediment deposition within each zone.

[Locations are shown in fig. 5.]

	Size		Sediment deposition	
	(mi^2)	(ft^2)	Volume (ft^3)	Thickness (in.)
North Channel				
Zone 1	0.055	1,533,312	767	6.0×10^{-3}
Zone 2	.049	1,366,041	139	1.2×10^{-3}
Zone 3	.121	3,373,286	33	1.2×10^{-4}
Zone 4	.223	6,216,883	5.6	1.1×10^{-5}
Pumpkin Patch Channel				
Zone 2	.010	278,784	35	1.5×10^{-3}
Zone 3	.017	473,932	8	2.0×10^{-4}
Zone 4	.023	641,203	1.4	2.6×10^{-5}

Results of this analysis indicate that the thickness of sediment accumulation in any given area of the bay as a result of bridge-construction activities will be negligible. Thus, the sandy benthic habitats to the west of the bridge are unlikely to be inundated with fine sediments and will not become mud habitats. Also, the metals and organic compounds associated with the suspended sediments will not be deposited at any one location in quantities appreciably greater than present background levels.

Most of the bottom material consisting of sand- and silt-sized particles that is resuspended by bridge-construction activities will be redeposited within the North Bay and Pumpkin Patch Channels within 6,700 ft and 3,721 ft of the bridge, respectively. The remaining fine material may be deposited in the shallow areas adjacent to these channels during flood tide if the ambient energy conditions permit, or they will be carried further down Pumpkin Patch and North Channels, where they will be deposited or eventually carried from the bay. Either way, the fine sediments and their associated contaminants will probably become widely dispersed and are unlikely to be deposited to an appreciable thickness at any one location.

SUMMARY

Hydraulic Characteristics

Net water transport measured for one synodic month from April 15 to May 14, 1984 through the North Channel bridge cross section was 0.67×10^8 ft^3 from west to east. During certain periods, however, the net transport was either negligible or east to west. Analysis of the head loss in the vicinity of North Channel bridge indicates that the proposed bridge will not constrict flow and therefore should not have any measurable effects on the net water transport.

Qualitative anlysis of the observed bay-bottom configurations at the North Channel bridge and North Channel railroad bridge indicates that local scour at the proposed bridge, although pronounced, should be less than beneath the present bridge because the total area of piles and piers will be 50 percent smaller. General scour should remain unchanged because the width constriction at the proposed bridge is similar to that of the present bridge.

Sediment Characteristics

The results of sediment oxygen demand and sediment-and-water mixing experiments indicate that the effects of bottom-sediment suspension will be virtually undetectable in the water column. The large volume of water passing the bridge during a given tide cycle will dilute the metals and nutrients released from the suspended sediments to several orders of magnitude below detection limits. In addition, the biochemical oxygen demand of the suspended bottom sediments is about 5 orders of magnitude less than background conditions in the North Channel area of Jamaica Bay.

The bottom sediments in the vicinity of North Channel bridge are, in general, of equal or better chemical quality than those throughout the rest of

Jamaica Bay. The metals concentration of bottom sediments in the North Channel bridge vicinity are much lower than in Grassy Bay but slightly greater than those in the western part of the bay. As expected, the metals seem to be associated with fine-sized particles and are likely to be transported with these particles after suspension. The significance of organic-compound concentrations in bottom sediments at the North Channel Bridge is difficult to interpret because data are scant; however, concentrations of PCB's and dieldrin in the bottom sediments at the North Channel bridge are lower than those measured elsewhere in Jamaica Bay during previous studies.

Sediment Transport and Deposition

A semiquantitative analysis of sediment transport and deposition indicates that the thickness of sediment deposition resulting from bridge construction will be small (less than 0.12 in) at any given location within the bay. In addition, the relatively small proportion of the bottom sediments consisting of fine-sized material are likely to stay in suspension for several tidal cycles and therefore will become widely dispersed. This means that the sandy benthic habitats to the west of the bridge are unlikely to be inundated with fine-sized sediments or become mud habitats.

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