CWA 10-3

CLEAN WATER

POLLUTION CONTROL IN THE RARITAN BAY AREA

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION • U. S. DEPARTMENT OF THE INTERIOR
HUDSON-DELAWARE BASINS OFFICE, EDISON, NEW JERSEY

POLLUTION CONTROL IN THE RARITAN BAY AREA*

by

Lester M. Klashman, Kenneth H. Walker and Richard T. Dewling**

Introduction

The Federal Water Pollution Control Act, as amended, provides that pollution of interstate waters which endangers the health or welfare of any person is subject to abatement under procedures described in Section 10 (33 USC 466g) of the Act. On the basis of reports, surveys and studies the Surgeon General of the Public Health Service, having reason to believe that pollution of the interstate waters of Raritan Bay and adjacent waters was endangering the health and welfare of persons of the States of New York and New Jersey, called a conference on the pollution of these waters. The aim of such a conference was to review the existing water quality problems, establish a basis for future action by all parties concerned, and to give States, interstate agencies, localities and industries an opportunity to take any indicated remedial action under State and local law.

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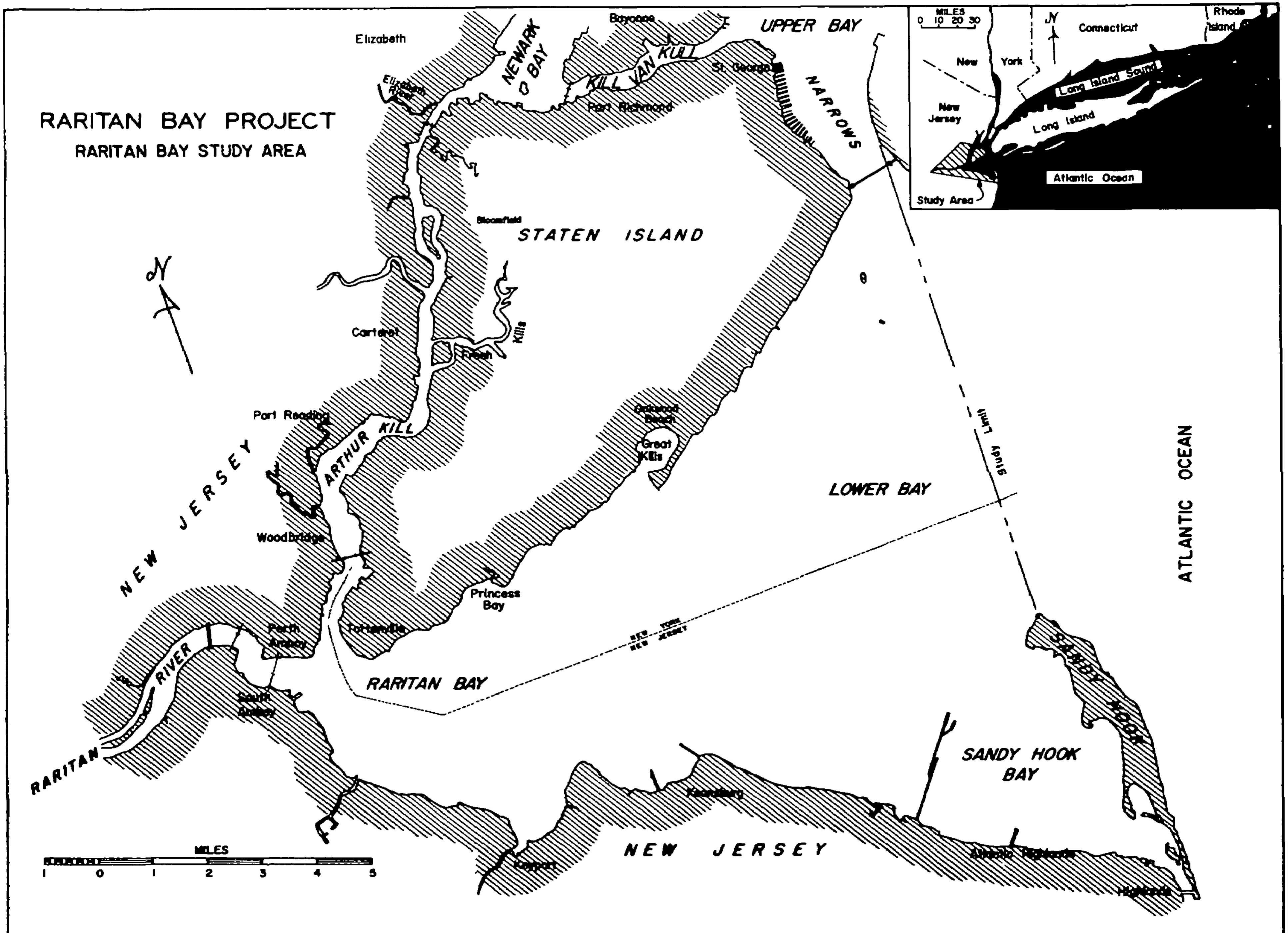
At the first session in August 1961, conferees requested a study by the Public Health Service to obtain scientific data for further control of pollution. Accordingly, the Raritan Bay Project was established to carry out such a program. The second session of the conference was held in May 1963. At that time the Project reviewed its activities through December 1962 and was requested by the conferees to continue its studies. On January 1, 1966, Congress transferred water pollution control activities from the Public Health Service to the Federal Water Pollution Control Administration. In May 1966, a Presidential reorganization transferred the Administration to the Department of the Interior, which continued the Raritan Bay Project. Final recommendations, which are presently being implemented, were presented to the conferees for adoption in May 1967. In this interim period, pending completion of proposed abatement procedures, surveillance activities are being carried out by the Project staff.

Objective: Clean Water

The objective of the Project was to develop the scientific data necessary for the conferees to establish an effective program for the abatement and control of pollution in the study area (Figure 1), which includes Lower, Sandy Hook and Raritan Bays, a portion of the Narrows, Arthur Kill, the tidal reach of the Raritan River and other small tributaries to the above mentioned waterways.



RARITAN BAY PROJECT
RARITAN BAY STUDY AREA
STATEN ISLAND
NEW JERSEY
ARTHUR KILL
KILL VAN KULL
NEWARK BAY
UPPER BAY
NARROWS
LOWER BAY
RARITAN BAY
RARITAN RIVER
SANDY HOOK BAY
SANDY HOOK
ATLANTIC OCEAN
Study Limit
NEW YORK
NEW JERSEY
Elizabeth
Bayonne
Port Richmond
St. George
Carteret
Fresh Kills
Port Reading
Great Kills
Woodbridge
Princess Bay
Perth Amboy
Tottenville
South Amboy
Keansburg
Keyport
Atlantic Highlands
Highlands
MILES
1 0 1 2 3 4 5
MILES
0 10 20 30
Connecticut
New York
New Jersey
Rhode Island
Long Island Sound
Long Island
Atlantic Ocean
Study Area

FIGURE I

Waters of the study area are presently utilized for industrial water supply, navigation, commercial fin and shellfishing, and a variety of recreational activities. However, full utilization of these waters is presently restricted by unsuitable water quality. The present estimated annual value of water use is $2.0 million; 90% of which is associated with recreation. With suitable quality, future potential value of these waters could be at least $19.0 million annually.

Studies of water currents and dispersion patterns indicate that Raritan Bay is affected by materials discharged into waters outside the immediate limits of the Project study area. Hence, the suggested control program considered the study area as a part of a system which includes Upper Bay, Kill Van Kull and Newark Bay.

Sources of Pollution

Major pollutional loads to the study waters are presented in Table I. Examination of these data indicates the large demand placed upon the assimilative capacity of these waters by the discharge of treated and untreated municipal and industrial wastes. Raritan Bay and Arthur Kill receive directly more than 480 million gallons per day (MGD) of wastes from a tributary population exceeding 1.3 million people. These discharges represent a Biochemical Oxygen Demand (BOD) loading of 430,000 lbs/day.

TABLE I

MUNICIPAL AND INDUSTRIAL WASTE LOADINGS[1]

Type Source	Flow MGD	Loadings (lbs/day) BOD	Suspended Solids	Tributary Population	Population Equivalent (BOD) Discharged
			DISCHARGES TO RARITAN BAY		
Municipal	72.1	182,500	40,560	507,800	1,069,200
Industrial	0.1 2/	2,500			14,700
Total	72.2 2/	185,000			1,083,900
			DISCHARGES TO ARTHUR KILL		
Municipal	81.8	138,360	55,350	831,000	812,750
Industrial	367.3 2/	104,640			615,000
Total	449.1 2/	243,000			1,427,750
			DISCHARGES TO RARITAN RIVER		
Municipal	2.0	1,605	845	20,365	9,430
Industrial	85.7 2/	70,100			421,000
Total	87.7 2/	71,707			430,430
			DISCHARGES TO STUDY AREA		
Municipal	155.9	322,465	96,755	1,359,165	1,891,380
Industrial	453.1	177,240			1,050,700
Total	609.0	499,705			2,942,080
			DISCHARGES TO UPPER BAY		
Municipal	915.9	808,510	645,100	3,815,100	4,758,400
Industrial	N.D. 3/	N.D.	N.D.	N.D.	N.D.
Total	915.9	808,510	645,100	3,815,100	4,758,400

NOTES: 1. Does not include additional wastes loadings from recreational and commercial vessels, or from stormwater overflow.

2. Excludes flow from power generating industry.

3. No data available.

The discharge of additional wastes in adjacent waters increases the magnitude of impact of the direct loads. When discharges to Upper Bay and Raritan River are included the total wastes volume approaches 1,500 MGD, which represents a BOD loading of greater than 1,300,000 lbs/day from a population exceeding 5.0 million people.

Contamination by pollutants other than BOD from these same sources is also a significant problem. Bacteriological pollution results from the discharge of more than 900 MGD of unchlorinated and raw municipal wastes emanating from a tributary population of 3.8 million persons. Such pollution constitutes a definite hazard to the health of persons having contact with these waters.

Nearly 75% of the total wastes volume is from industry. This results in pollution of study waters by a variety of contaminants in addition to oxygen consuming material. Pollutants such as oil, phenol, phosphate and nitrogen result in unsightly conditions, destruction of desirable aquatic life, tainting of fish and shellfish and eutrophication of the water.

Additional pollution results from the discharge of more than 1.0 billion gallons per day of "hot" cooling water from power generating plants adjacent to these waters. Further contamination occurs in localized areas due to the discharge of wastes from recreational and commercial vessels. The overflow of sewage from combined stormsanitary sewer systems also represents an important factor in pollution of these waters.

Investigative Program

Based upon a review of existing data a sampling program was designed which would permit an evaluation of the variations in water quality and long-term trends. The Project conducted an intensive program, with weekly sampling at each station (Figure 2) during the 13-month period from August 1962 through September 1963. From September 1963 to May 1966 the Project conducted a surveillance program which involved collecting of monthly samples at selected stations in the Bay and Kill.

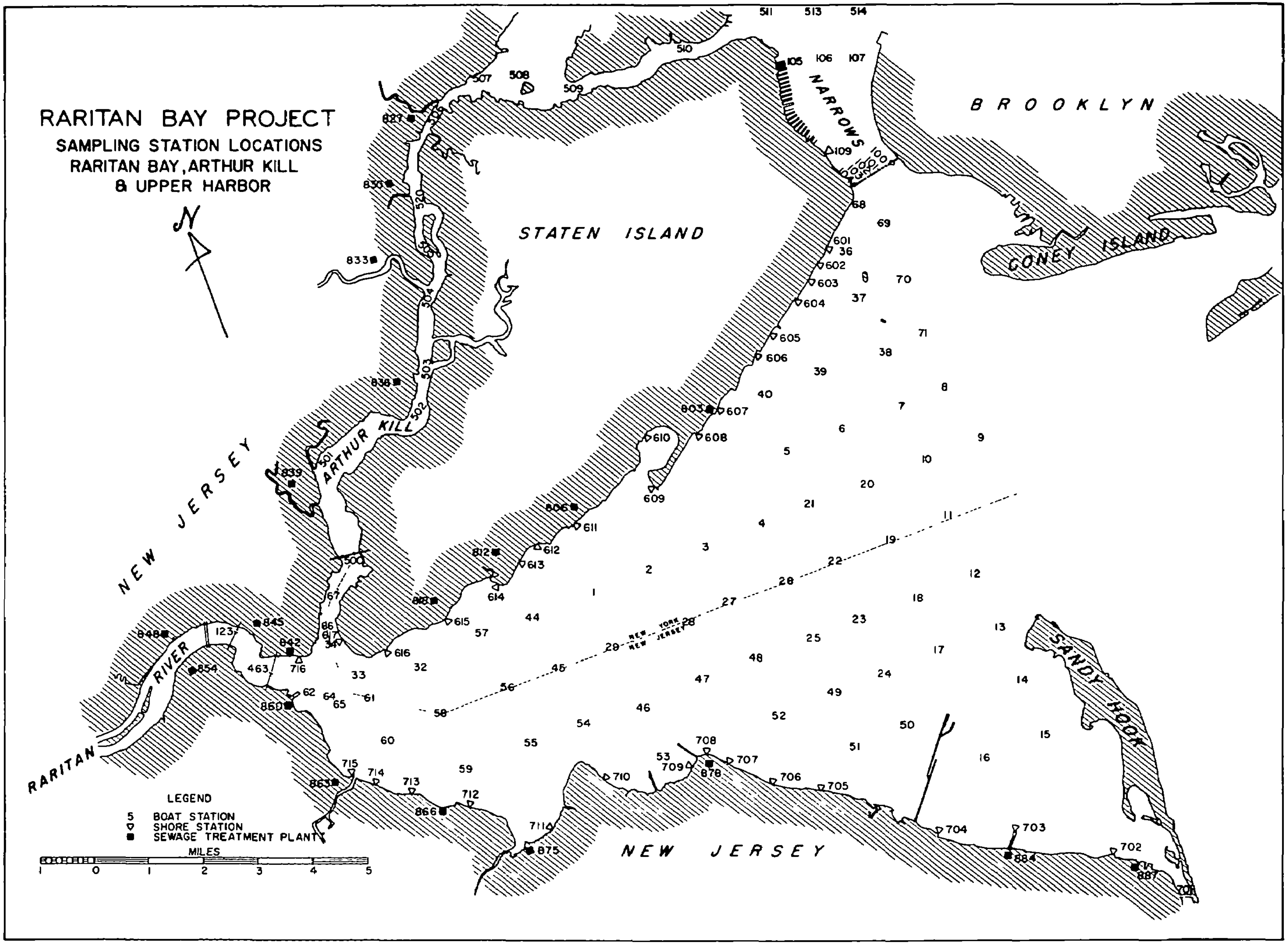

RARITAN BAY PROJECT
SAMPLING STATION LOCATIONS
RARITAN BAY, ARTHUR KILL
& UPPER HARBOR
N
STATEN ISLAND
BROOKLYN
CONEY ISLAND
NARROWS
NEW JERSEY
ARTHUR KILL
RARITAN RIVER
SANDY HOOK
NEW YORK
NEW JERSEY
LEGEND
5 BOAT STATION
▽ SHORE STATION
■ SEWAGE TREATMENT PLANT
MILES
1 0 1 2 3 4 5

FIGURE 2

The intensive sampling program was designed to permit mathematical analyses of the variations noted in parameter values. The surveillance operation was pursued so as to maintain updated water quality data and to provide information on any changes which might have occurred during the period of surveillance.

Major activities undertaken by the Project during this study included, but were not necessarily limited to:

1. Simultaneous sampling of Raritan Bay, the Arthur Kill and waste treatment plant effluents emptying into these waters so as to permit assessment of relationships between the waste loads and water quality.

2. Intensive bacteriological sampling of Raritan Bay and shoreline, entrant waters, and wastewater treatment plants discharging to the Bay to determine bacterial densities.

3. Biological investigations designed to define the area of biological degredation, with particular emphasis on the benthic populations.

4. Chemical evaluation of the existing water quality in the Bay as well as characterizing waste effluents, with particular emphasis being on nutrients and the oxygen demanding components.

A number of special investigations were undertaken by the Project to provide further data on water pollution problems in the study area. Included were an examination of water movement and dispersion patterns within Raritan Bay; an evaluation of the effects on water quality of combined sewer overflows; mathematical analyses to explain the variations found in the chemical and bacteriological analysis of Bay water samples; a study of the relationship between chlorination of wastewater treatment plant effluents and bacteriological densities in Raritan Bay; determination of the bacteriological and chemical quality of shellfish taken from the Bay; and isolation of certain pathogenic bacteria from study area waters, sewage effluents and shellfish. Results of certain of these special investigations are discussed later in this paper.

Photosynthesis - Key Element in Maintaining Bay DO

Variation in dissolved oxygen throughout the Bay, which has an average chloride concentration of approximately 14,000 mg/l, was attributed to a predominant annual variation with secondary effects caused by tidal and diurnal cycles (Figure 3). During the winter, values throughout the Bay were 9 - 10 mg/l with virtually no dissolved oxygen gradient. During the spring months dissolved oxygen values remained at these levels, however, concentration gradients began to appear, with lower concentrations near the Narrows and near the confluence of the Raritan River and Arthur Kill. During the summer period, gradients were more pronounced with dissolved oxygen values ranging from 10 mg/l in the center of the Bay to 4 mg/l in the vicinity of the Narrows, Raritan River and Arthur Kill. During autumn the gradient

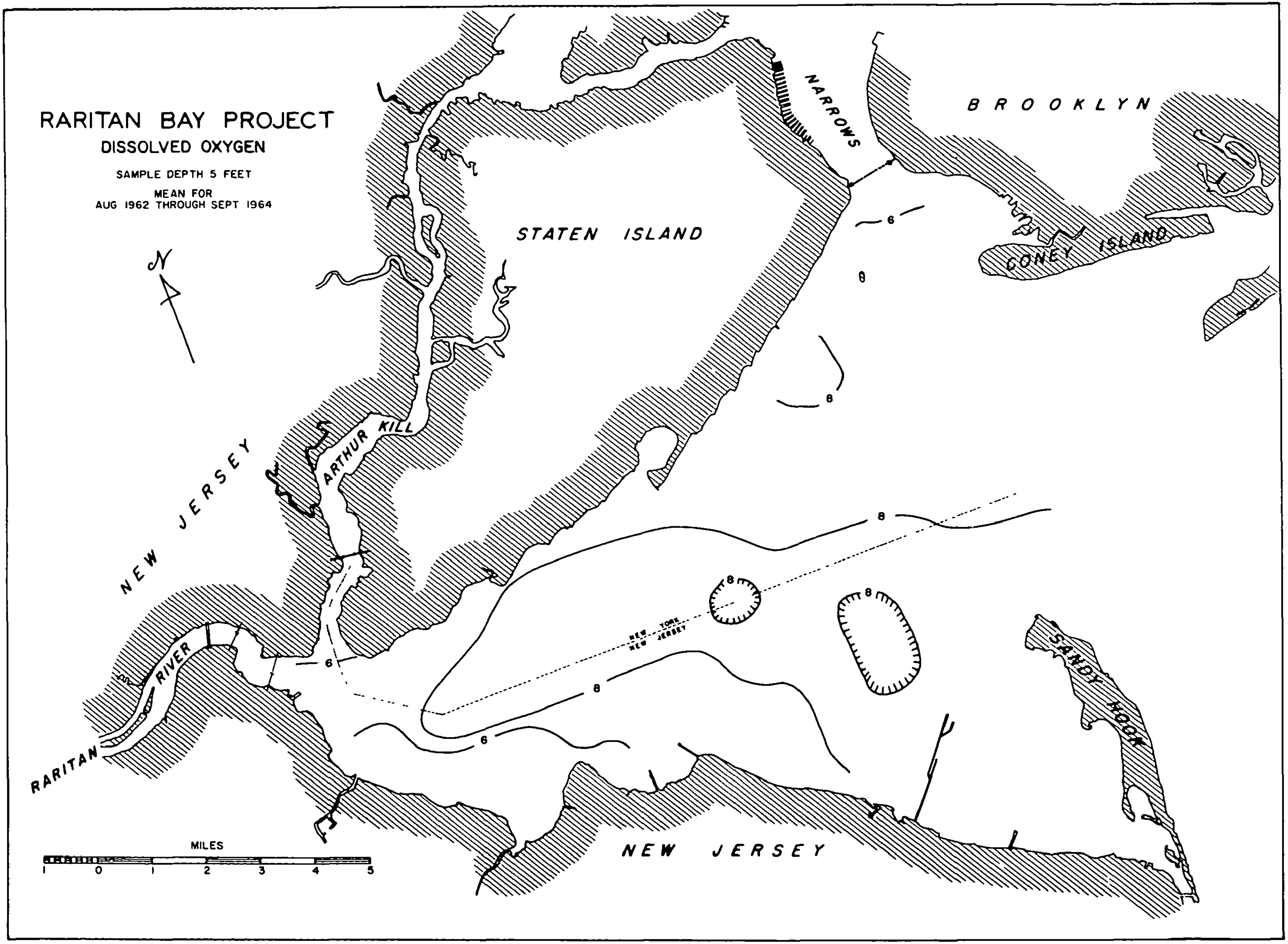

RARITAN BAY PROJECT
DISSOLVED OXYGEN
SAMPLE DEPTH 5 FEET
MEAN FOR
AUG 1962 THROUGH SEPT 1964
N
STATEN ISLAND
NARROWS
BROOKLYN
CONEY ISLAND
ARTHUR KILL
NEW JERSEY
RARITAN RIVER
NEW YORK
NEW JERSEY
SANDY HOOK
NEW JERSEY
6
8
8
8
8
8
8
6
6
MILES
1 0 1 2 3 4 5

FIGURE 3

essentially disappeared and dissolved oxygen concentrations throughout the Bay were on the order of 5 to 7 mg/l. From a dissolved oxygen standpoint, autumn appears to be the most critical period throughout the Bay, although near the Narrows and the junction of the Raritan River and Arthur Kill, equally critical dissolved oxygen levels were found during the summer.

Photosynthetic production of oxygen by marine organisms was a major factor in maintaining Bay dissolved oxygen levels. Biological surveys revealed that an increase in netplankton concentration was accompanied by an increase in dissolved oxygen levels. Increases in the zooplankton population, on the other hand, were accompanied by decreasing dissolved oxygen levels with a simultaneous occurrence of lowest dissolved oxygen concentrations and peak zooplankton populations.

Respiration of the dominant zooplankters found during peak populations utilized as much as 37 mg/l per day of oxygen. This large loss of oxygen due to respiration was offset, at least partially, by simultaneous blooms of nanoplankton which are active oxygen producers.

Special studies were conducted at two stations in Raritan Bay to determine the net effect of photosynthetic production and respiration by marine organisms. The results, presented in Figure 4, suggests that oxygen production in the Bay is essentially limited to the top 11 feet with peak production occurring in the upper 6 feet. Between 38 and 55

OXYGEN PRODUCTION, UPTAKE & YIELD

PHOTOSYNTHETIC ZONE

RARITAN BAY

AUGUST 1964

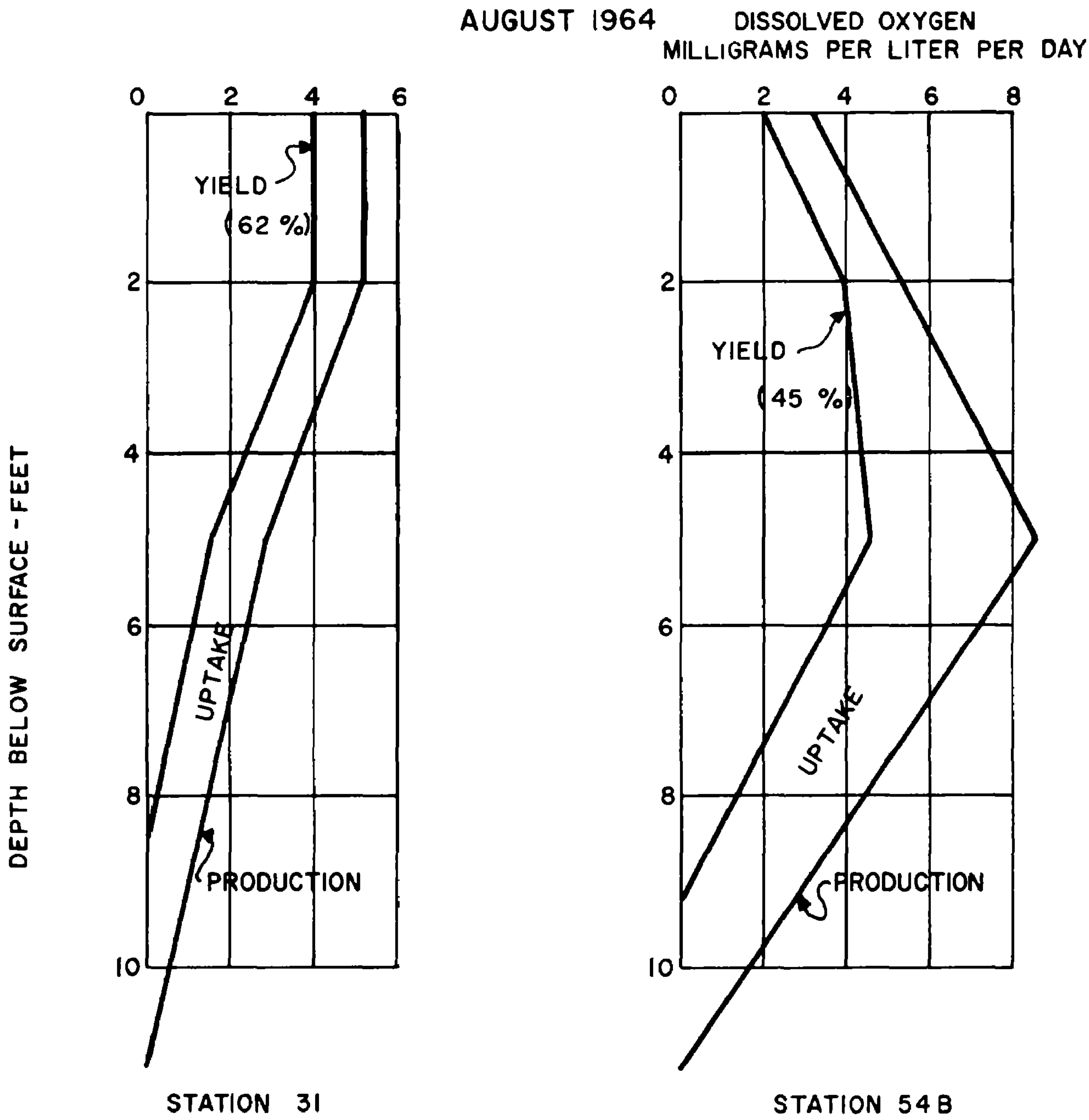


FIGURE 4

percent of the oxygen produced by photosynthesis was consumed by respiration, with the remainder being made available to the waters of the Bay.

Bacteriological Studies - Shellfish Plus Overlying Waters

Analyses were performed for both total and fecal coliform by both the MPN and MF procedures and for fecal streptococcus by only MF procedures. Figure 5 presents the mean MPN coliform count for the Bay. High densities were found both in the vicinity of the Narrows and at the junction of the Arthur Kill and Raritan River. From these two sources coliforms appear to radiate out into the Bay. Those stations with the lowest mean count formed an apparent edge between the two radiating sources appearing as a straight band running from Princess Bay, Staten Island, New York to Sandy Hook Bay, New Jersey. Geometric mean counts for MPN confirmed coliform ranged from 10,000/100 ml at the Narrows, and 7,000/100 ml at the mouth of the Raritan River to less than 50/100 ml in Sandy Hook Bay. The high fecal coliform densities and the ratio of fecal coliform to fecal streptococcus group organisms, which are characteristic of human feces, strongly suggested that contamination in the study area waters resulted from human sources.

The Project conducted bacteriological analyses on 391 shellfish samples taken from 50 stations throughout Raritan Bay. Analyses were performed for MPN total coliform, MPN fecal coliform, and for the presence of Salmonella bacteria. The results are summarized in Table II.

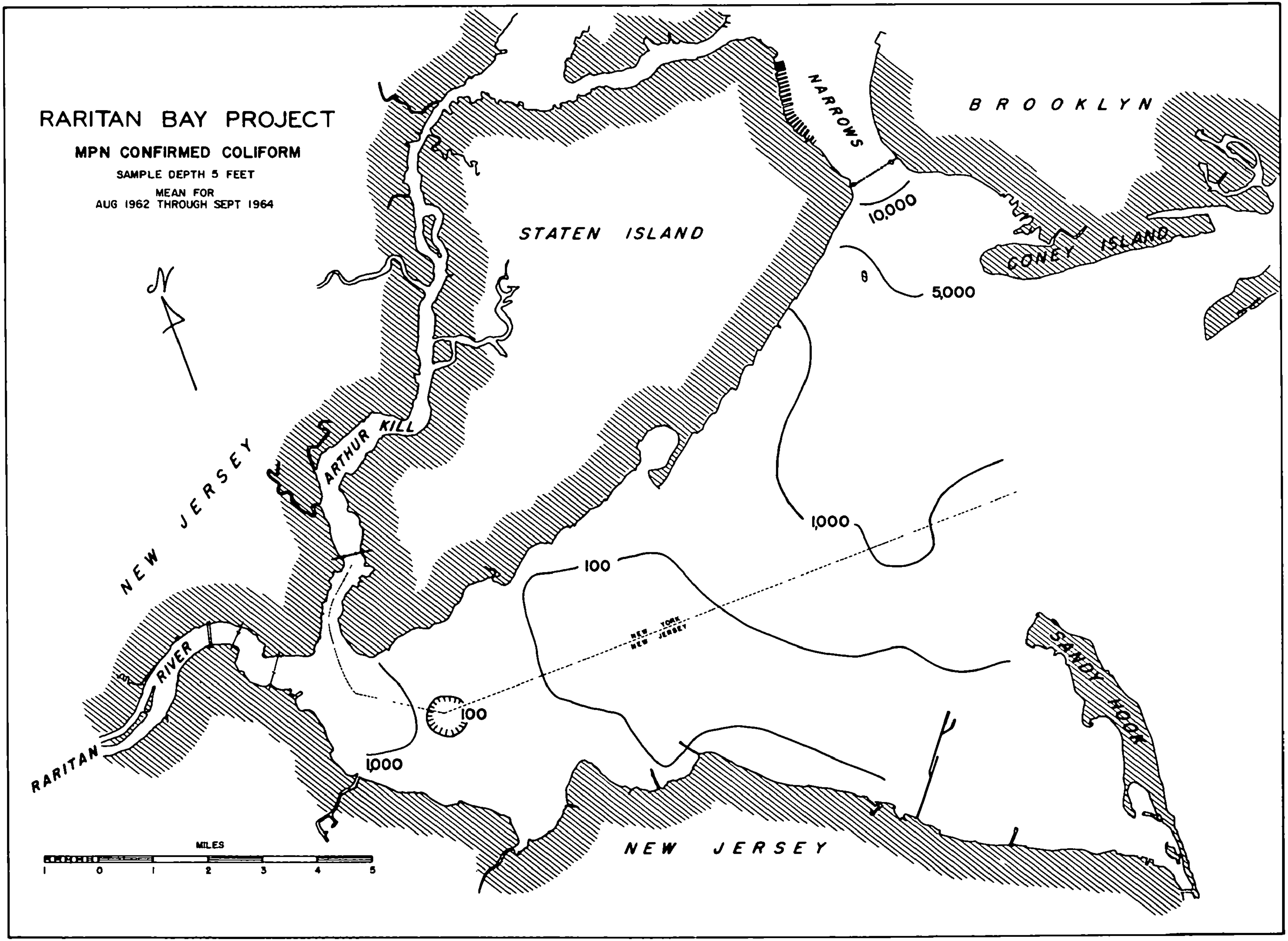

RARITAN BAY PROJECT
MPN CONFIRMED COLIFORM
SAMPLE DEPTH 5 FEET
MEAN FOR
AUG 1962 THROUGH SEPT 1964
N
STATEN ISLAND
NARROWS
BROOKLYN
CONEY ISLAND
10,000
5,000
1,000
100
100
1,000
ARTHUR KILL
NEW JERSEY
RARITAN RIVER
NEW YORK
NEW JERSEY
SANDY HOOK
NEW JERSEY
MILES
1 0 1 2 3 4 5

FIGURE 5

TABLE II

RESULTS OF BACTERIOLOGICAL EXAMINATION OF SHELLFISH MEATS

Station	Total Coliform, MPN/100 g. No.	Min	Max	Geom Mean	Fecal Coliform, MPN/100 g. No.	Min	Max	Geom Mean	Salmonella Isolations No.	Serotypes
1	8	<20	490	180	8	<20	330	120		
2	8	<20	1,700	550	8	<20	460	140		
3	8	<20	2,300	700	8	<20	2,300	370		
4	9	<20	24,000	3,200	9	<20	7,900	970		
6	7	<20	17,000	5,700	7	<20	13,000	3,100	4	S. st. paul; S.anatum;S.montevideo; S. litchfield
7	8	<20	160,000	39,000	8	<20	92,000	16,000	2	S. oranienburg; S.derby
10	7	<20	35,000	8,700	7	<20	11,000	2,600	2	S.derby; S.infantis
13	6	<20	7,900	1,400	6	<20	2,300	410		
14	8	<20	330	100	8	<20	130	45		
15	8	<20	330	120	8	<20	20	20		
16	8	<20	330	120	8	<20	230	52		
17	9	<20	2,300	580	9	<20	790	210		
18	7	<20	4,900	1,600	7	<20	1,300	350		
20	7	<20	13,000	4,000	7	<20	2,300	1,100		
21	6	<20	13,000	4,900	6	<20	3,300	1,300	1	S.derby
22	8	<20	3,300	1,200	8	<20	3,300	740	1	S.derby
23	8	<20	7,000	1,400	8	<20	790	260		
24	8	<20	4,900	1,300	8	<20	1,300	280		
25	9	<20	35,000	5,700	9	<20	3,300	1,000	1	S.tennessee
26	9	<20	16,000	2,800	9	<20	3,500	610		
27	8	<20	3,300	1,000	8	<20	2,200	620		
28	8	<20	1,300	600	8	<20	490	160	1	S.derby
29	7	<20	790	260	7	<20	490	110		
30	7	<20	460	200	7	<20	170	71		
31	8	<20	460	210	8	<20	230	95		
32	8	<20	7,900	1,400	8	<20	950	320		
33	7	<20	2,300	930	7	<20	790	350		
36	8	<20	92,000	13,600	8	<20	35,000	4,700	1	S.derby

TABLE II (Cont.)

RESULTS OF BACTERIOLOGICAL EXAMINATION OF SHELLFISH MEATS

	Total Coliform, MPN/100 g.				Fecal Coliform, MPN/100 g.				Salmonella Isolations	
Station	No.	Min	Max	Geom Mean	No.	Min	Max	Geom Mean	No.	Serotypes
37	7	<20	24,000	6,600	7	<20	4,900	1,700	1	S.anatum
39	9	<20	24,000	5,200	9	<20	24,000	3,500	1	S.6,7:K mono.
40	8	<20	22,000	5,600	9	<20	7,900	2,100	3	S.derby;S.anatum; S.6,7 non.mot.
41	9	<20	3,300	1,100	9	<20	490	150		
42	8	<20	3,500	540	8	<20	310	70		
43	7	<20	490	150	7	<20	140	67		
44	8	<20	2,300	630	8	<20	230	77		
45	7	<20	490	190	7	<20	140	52	1	S.typhimurium
46	8	<20	230	97	8	<20	80	31		
47	8	<20	1,300	350	8	<20	230	76	2	S.6,7:non.mot; S.6,7:K mono.
48	8	<20	3,300	780	8	<20	790	150		
49	8	<20	13,000	2,000	8	<20	1,300	300		
50	8	<20	3,300	600	8	<20	490	92		
51	7	<20	2,300	400	7	<20	2,300	340		
52	7	<20	4,900	860	7	<20	460	110		
53	8	<20	2,100	380	8	<20	130	37		
54	7	<20	7,900	1,300	7	<20	490	90		
56	7	<20	490	180	7	<20	170	44	2	S.infantis; S.muenchen
57	8	<20	4,900	820	8	<20	490	160		
58	6	<20	3,300	1,200	6	<20	230	120		
61	6	110	7,000	1,400	6	<20	4,600	820		
73	6	<20	2,300	400	6	<20	170	45		

Samples from 12 of the 50 stations had geometric mean total coliform densities greater than 2,400 per 100 grams of shellfish meat. The geometric mean fecal coliform density in shellfish taken from these same 12 stations ranged from 610 to 16,000 per 100 grams. The presence of high total coliform densities appeared to show some correlation with water temperature. None of the shellfish taken from waters with temperatures less than 8.5°C had total coliform MPN's of 2,400 or more per 100 grams. The 12 stations having geometric mean coliform densities greater than 2,400 per 100 grams were located in the northerly sector of the Bay in an area extending generally south of Staten Island to and across the New York-New Jersey state line.

Salmonellae were isolated from clam meats collected at 14 of the 50 sampling stations. Of these 14 stations, nine also showed geometric mean total coliform densities greater than 2,400 per 100 grams of clam meat. The geometric mean coliform density in shellfish from the other five stations ranged from 180 to 1,200 per 100 grams. A total of 23 *Salmonella* isolations were made with 13 serotypes identified. *Salmonella derby* was the predominant serotype and was isolated in shellfish from seven of the 14 stations. Stations which showed the presence of Salmonella in the clam meats covered two general areas, one of which corresponded with the location of high coliform counts in the clam meats as described above. The second area was located along the New York-New Jersey state line, in an area bounded roughly by Great Kills, Staten Island, N. Y., and Keyport and Keansburg, N. J.

Chemical analyses of meats from shellfish taken from these 50 sampling stations indicated high phenol and mineral oil concentrations from a number of stations in the western sector of the Bay, with highest values associated with those stations nearest the mouths of the Arthur Kill and Raritan River. Specific analyses for a number of metals, including copper, chromium, zinc and lead, and for pesticide residues, revealed trace amounts in clam meats.

Pathogen Isolations from Sewage and Bay Waters

In an attempt to further evaluate the effects of Upper Bay and the Narrows on the eastern portion of Raritan Bay, studies were undertaken to isolate *Salmonella* and *Shigella* from sewers discharging into the Narrows, and from the waters of Raritan Bay and the Narrows.

No isolations could be made of *Shigella* organisms but a number of positive results were obtained for *Salmonella*. From October 1963 through April 1964, these organisms were isolated in four of seven samples taken from a sewer which discharges raw municipal wastes from Staten Island into Upper Bay just above the Narrows. Between October 1963 and July 1964 a total of 20 samples in the Narrows were analyzed, 40% of which were positive for *Salmonella*. A total of 15 different serotypes were identified, and as many as seven different serotypes were isolated from one sample. Areas of Staten Island shore closest to the Narrows showed the greatest frequency of *Salmonella* isolation. Five of 13 samples taken at South Beach were positive; at Midland Beach two of 14 samples showed Salmonella. No Salmonellae were recovered from samples further west at the Miller Field beach areas. Some of the same serotypes found in the Narrows were isolated from the bathing area samples. Although a limited number of samples were analyzed, the relatively small sample volume (2 liters) which was used for these determinations suggest a substantial density in these areas.

Attempts were made to isolate Salmonella from various locations in eastern Raritan Bay (See Figure 6) extending on a line from the Narrows southerly towards Sandy Hook. Of the 16 stations sampled, 10 were positive. Of the 48 samples processed, 27% contained Salmonella, and a total of 25 Salmonella isolations were made. S. derby was the predominant serotype, being isolated on eight different occasions, and was also the predominant serotype in the samples collected at the Narrows. Salmonellae were isolated below the Narrows as far as approximately six miles south of the Verrazano-Narrows Bridge.

Plankton and Benthic Populations Studied

During the period of study nanoplankton comprised 94% or more of the total phytoplankton population. At all sampling stations (See Figure 7) the nanoplankton population was high during the summer and low in the winter. Nanoplankton blooms developed as water temperatures increased sharply in May and June and showed peak densities coincident with peak water temperatures. During summer blooms nanoplankton comprised as much as 99.9% of the total plankton population. Netplankton

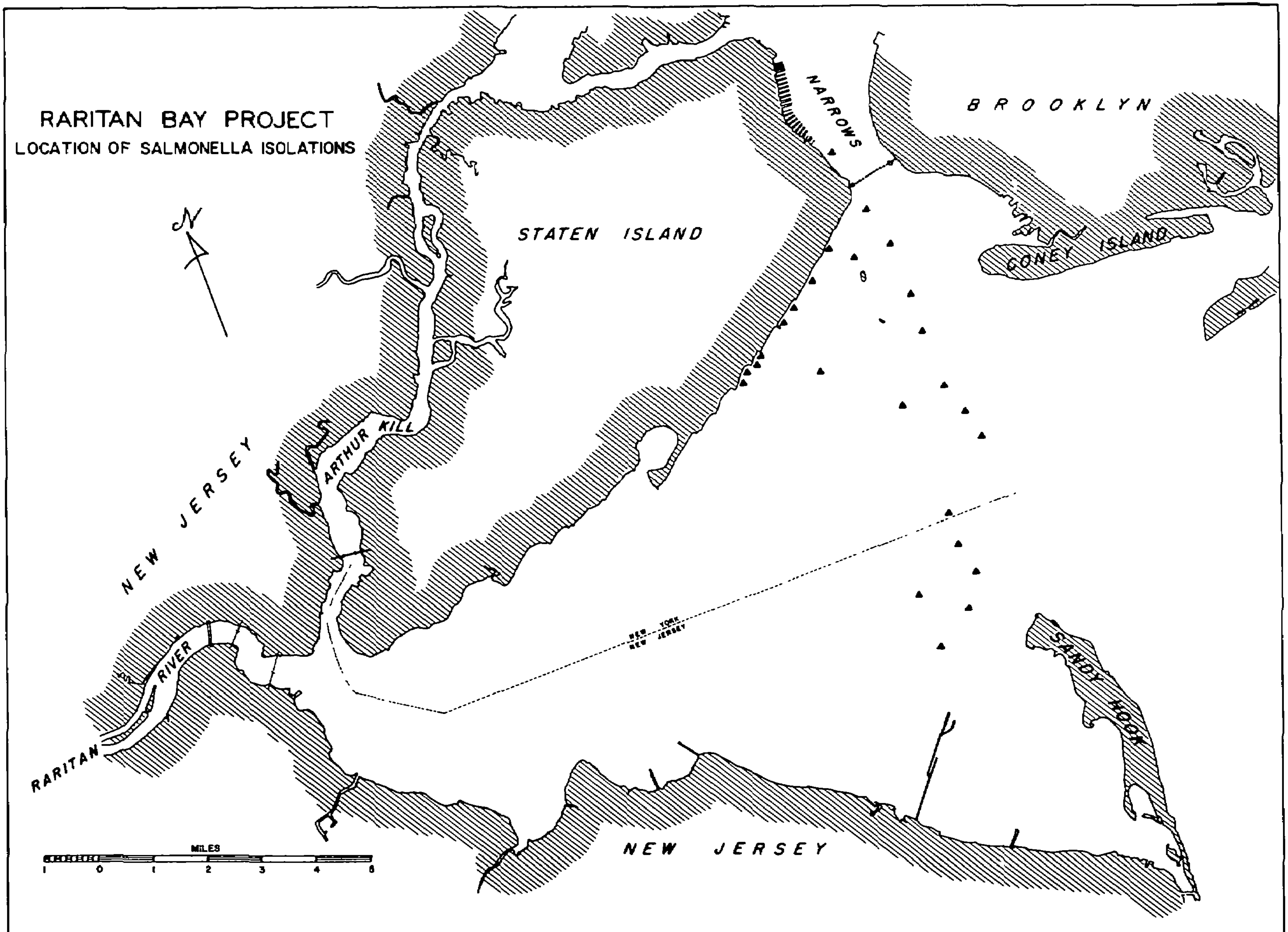

RARITAN BAY PROJECT
LOCATION OF SALMONELLA ISOLATIONS
N
STATEN ISLAND
NARROWS
BROOKLYN
CONEY ISLAND
ARTHUR KILL
NEW JERSEY
RARITAN RIVER
SANDY HOOK
NEW JERSEY
MILES
1 0 1 2 3 4 5

FIGURE 6

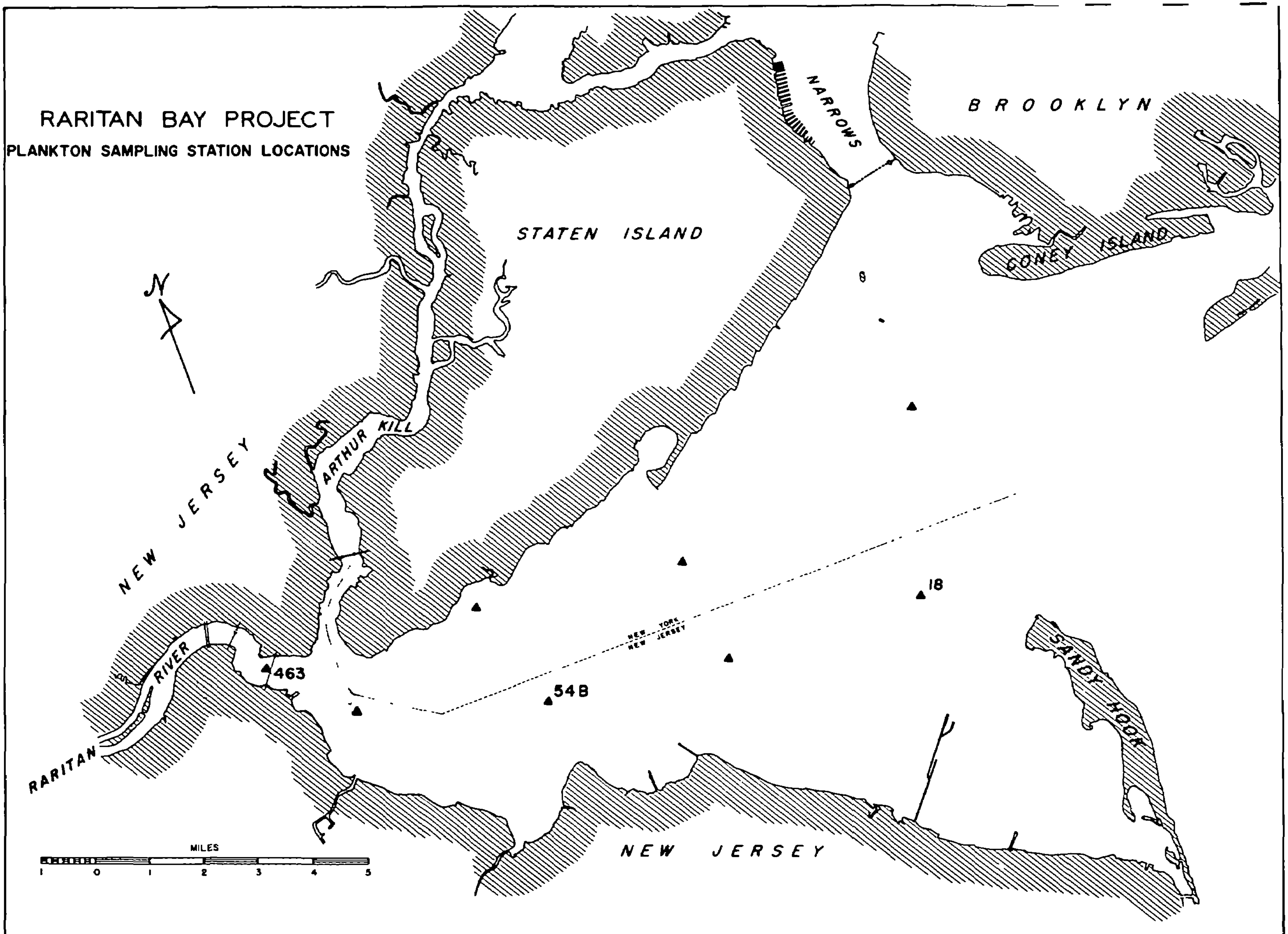

RARITAN BAY PROJECT
PLANKTON SAMPLING STATION LOCATIONS
N
STATEN ISLAND
NARROWS
BROOKLYN
CONEY ISLAND
ARTHUR KILL
NEW JERSEY
RARITAN RIVER
463
54B
18
NEW YORK
NEW JERSEY
SANDY HOOK
NEW JERSEY
MILES
1 0 1 2 3 4 5

FIGURE 7

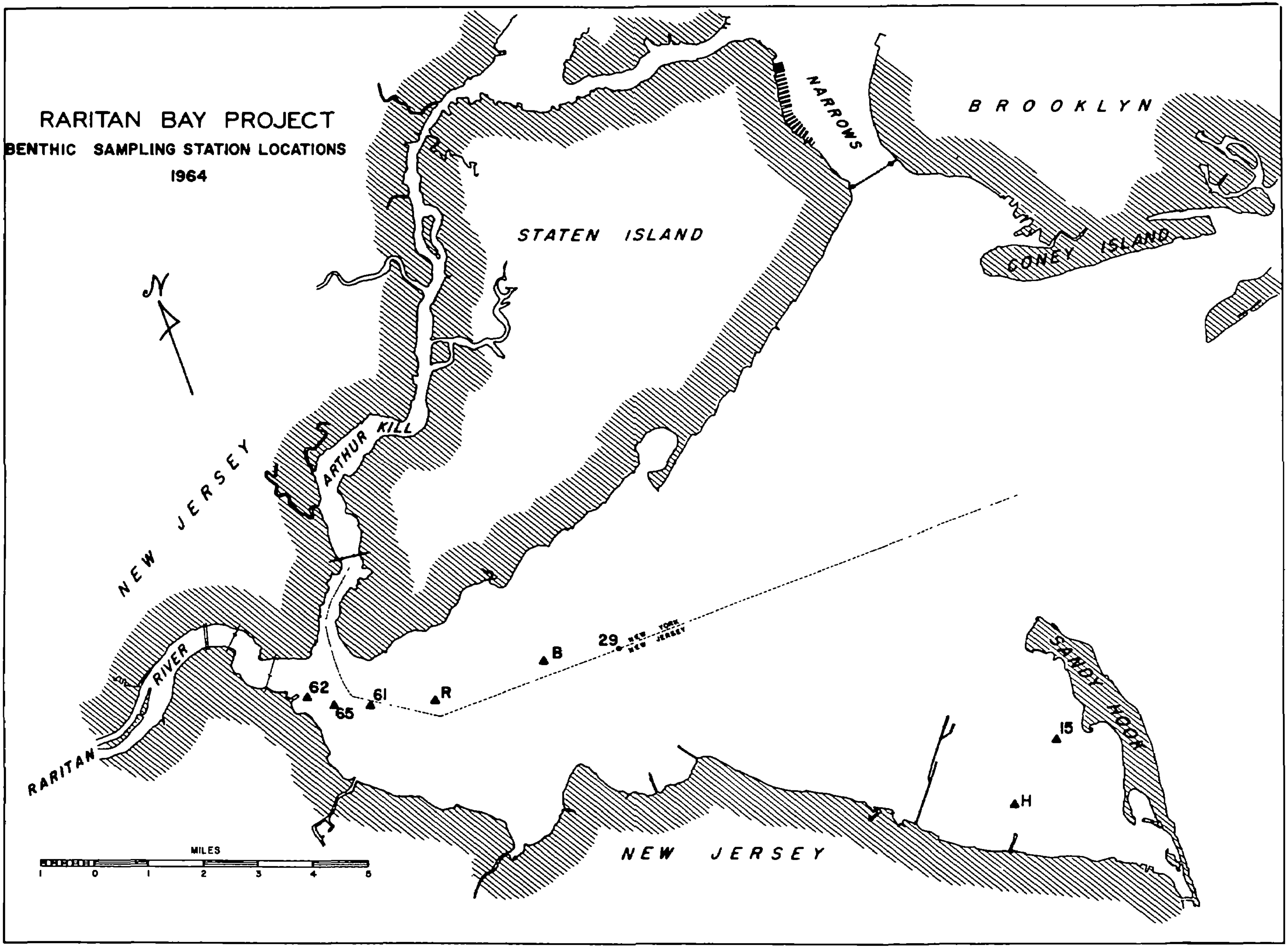
blooms occurred during the colder months, disappearing as temperatures reached 8 or 9°C; hence, netplankton densities were lowest during the summer and greatest in the spring. At their peak, spring blooms of netplankton constituted 27 to 48% of the total plankton population. In both 1962 and 1963 blooms of netplankton occurred during the first week of October at Station 18. Such fall blooms are a normal occurrence in coastal waters.

Phytoplankton populations were dominated by two algal species, *Nanochloris atomus* and *Skeletonema costatum*. The former, a green alga, comprised more than 50 to 99.9% of the nanoplankton community. *Skeletonema costatum*, a diatom, comprised from less than 1.0 to more than 99% of the netplankton population. During August and September 1962, and again in 1964, a dinoflagellate, *Peridinium trochoidum*, numerically dominated the netplankton population. This alga was not observed in quantitative samples collected during the summer of 1963.

Coincidental with plankton studies, levels of selected nutrients were determined at each of the plankton stations. These selected nutrients — total phosphorous, nitrate, organic nitrogen, ammonia — were always present in amounts sufficient to support the observed plankton populations.

Benthic Studies: Key Biological Tool

Benthic samples were collected in Raritan Bay (See Figure 8) and subjected to both chemical and biological analyses. Sediments were



RARITAN BAY PROJECT
BENTHIC SAMPLING STATION LOCATIONS
1964
STATEN ISLAND
BROOKLYN
NARROWS
CONEY ISLAND
ARTHUR KILL
NEW JERSEY
RARITAN RIVER
SANDY HOOK
NEW JERSEY
NEW YORK
NEW JERSEY
29
B
R
61
62
65
15
H
MILES
1 0 1 2 3 4 5

FIGURE 8

classified according to median grain size. Those stations with sediment composed of the smallest size particles had fewer animals than those areas with the larger grain size.

The types of benthic organisms and their relative numbers are presented in Table III. The polychaete, or segmented worms and amphipod crustaceans were the dominant benthic organisms. Tube dwelling worms, regarded as pollution tolerant organisms, were more numerous towards Stations 62 and B, indicating a greater degree of pollution in that area.

In May and August 1964, certain chemical analyses were performed on samples of bottom sediment. A comparison was made between these data and the average number of benthic species found at each station. With the exception of Station H the results presented in Figure 9 indicate a general decline in the level of Total Kjeldahl Nitrogen, BOD and COD with increasing distance from the more polluted stations. The higher concentrations at H were attributed to a small sewer outfall located in the immediate vicinity. In general, fewer benthic species were found at those stations having the higher concentrations of nitrogen.

Water Movement and Dispersion

Examination of the geographical structure of the study area suggests the hydraulic complexity of the system, due to interconnections between the bodies of water as well as other waters external to Raritan Bay and Arthur Kill. Any satisfactory pollution control program developed for Raritan Bay and Arthur Kill must be based on knowledge of the movement

TABLE III

PERCENTAGE OF BENTHOS AT REPRESENTATIVE STATIONS

	Station 62				Station B				Station 29				Station H			
1964	PW	AC	SC	O	PW	AC	SC	O	PW	AC	SC	O	PW	AC	SC	O
Feb.	0	0	0	0	76	6	0	18	67	17	0	16	8	92	0	0
May	100	0	0	0	65	15	0	20	33	66	0	1	15	85	0	0
Aug.	0	0	100	0	35	28	10	27	74	19	7	0	55	38	0	7

PW = Polychaete Worms
AC = Amphipod Crustaceans
SC = Soft Shell Clams
O = Others: All types of organisms that comprised separately less than 5% of the total.

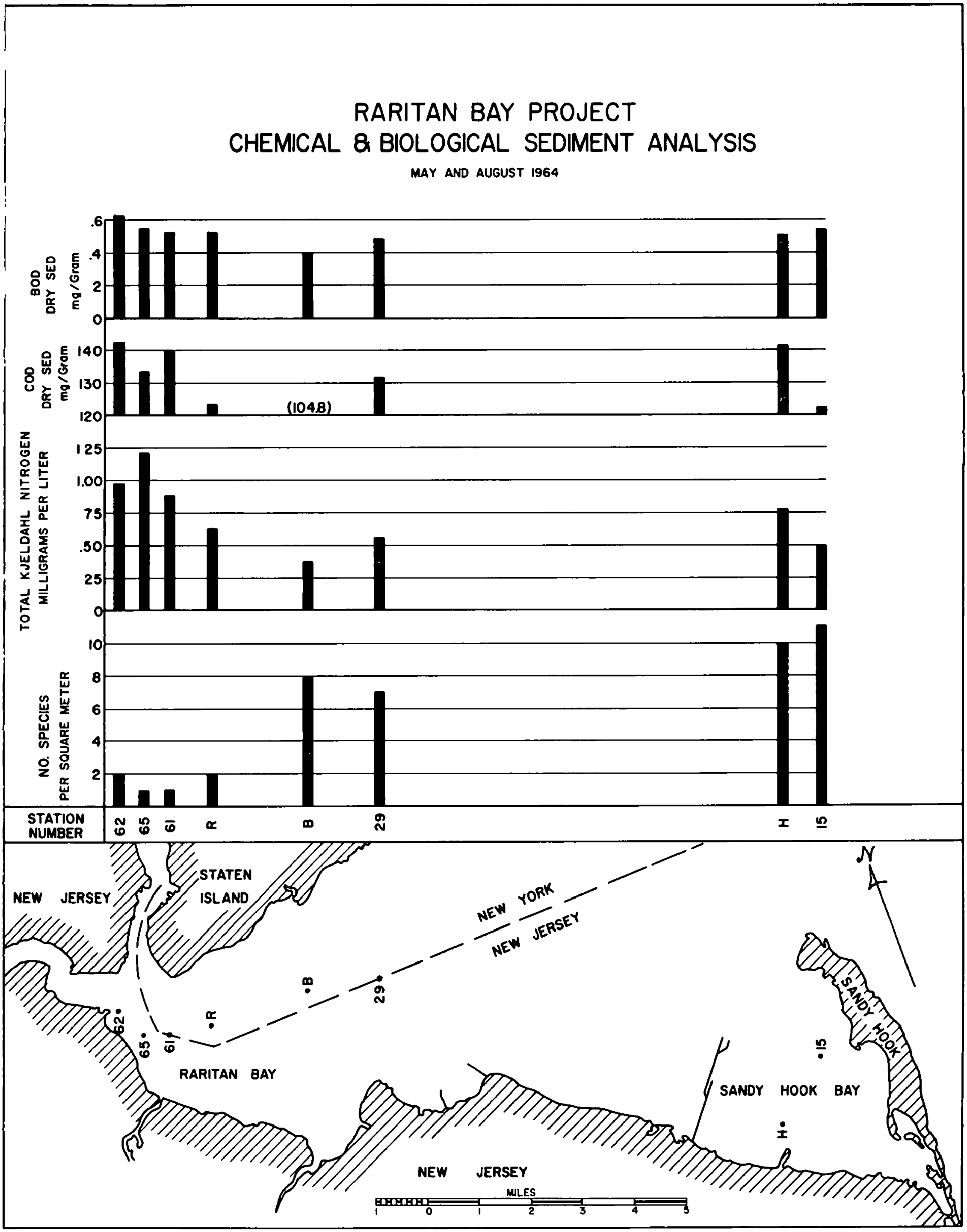

RARITAN BAY PROJECT
CHEMICAL & BIOLOGICAL SEDIMENT ANALYSIS
MAY AND AUGUST 1964
BOD DRY SED mg/Gram
COD DRY SED mg/Gram
(104.8)
TOTAL KJELDAHL NITROGEN MILLIGRAMS PER LITER
NO. SPECIES PER SQUARE METER
STATION NUMBER
62
65
61
R
B
29
H
15
NEW JERSEY
STATEN ISLAND
NEW YORK
NEW JERSEY
N
SANDY HOOK
RARITAN BAY
SANDY HOOK BAY
NEW JERSEY
MILES

FIGURE 9

of waters between these various bodies so as to recognize probable paths of flow of pollutional materials. Accordingly, the Project conducted investigations of water movement by tracer dye studies, geological investigations, and by reviewing available hydraulic model data.

Dye studies provided information on water movement and dispersion characteristics under conditions actually observed at the time of each dye release.

Dye release studies were made in the Raritan River, Arthur Kill, westerly portion of Raritan Bay and in Upper Bay to observe the interrelationship of these waters. Rhodamine B dye, used in all studies conducted by the Project, was added to the water as an instantaneous release. In all studies, except upper Raritan River, resulting movement of dye was monitored visually and by the use of fluorometers for as long as deemed advisable. During the monitoring phase, boats equipped with fluorometers and continuously recording meters cruised the dye mass to determine its movement, location of the limits, and the peak concentrations. Monitoring boats proceeded on a predetermined course —— established between known navigational aids —— at a fixed rate of speed. In addition to recording dye concentration, records were also maintained on time and boat course so as to permit proper correlation between an observed dye concentration and the exact location and time of such reading.

Results of the largest — 1,000 pounds — dye release, conducted in Upper Bay at high water slack, are shown in Figure 10 and summarized as follows:

- Material introduced in the northwest sector of the Upper Bay affects a broad area of Lower Bay, and is found on the Staten Island shore from Midland Beach to the Narrows within 6 hours of release;
- Within 32 hours of release such material affects a large area of Raritan Bay, and is found on the Staten Island shore from the Narrows to Great Kills, as well as on the Coney Island shore of Brooklyn, N. Y.;
- On an ebb current there was little lateral mixing across the Narrows, but lateral mixing does occur on the first flood current following release;
- Material moving from the release point on the first ebb passes along the western edge of the channel and the Staten Island shore before passing through the Narrows.

A geological investigation of Raritan Bay was made to obtain information on long term water movement and sediment distribution. In summary, the investigation found, based upon the sediment distribution

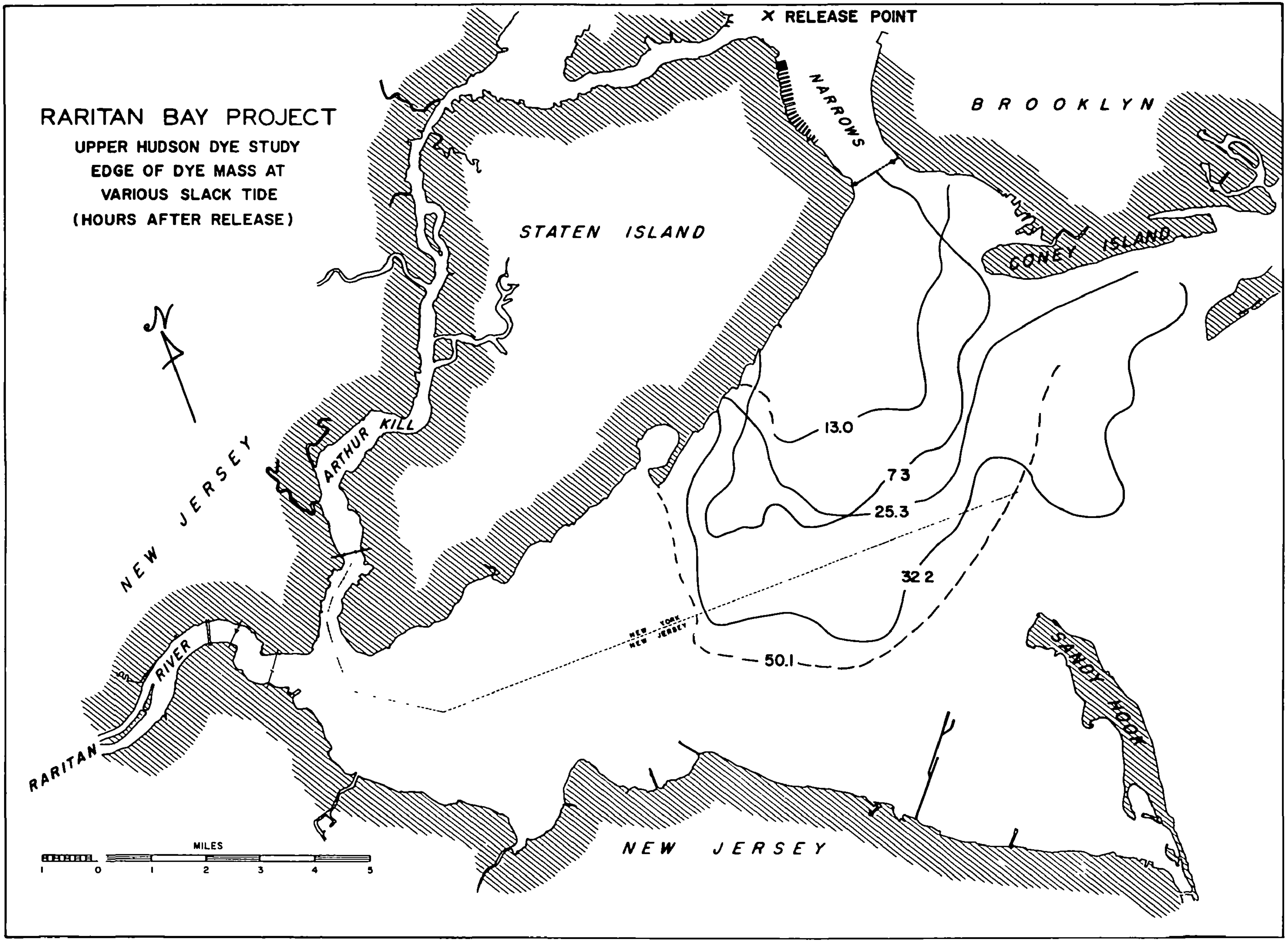

RARITAN BAY PROJECT
UPPER HUDSON DYE STUDY
EDGE OF DYE MASS AT
VARIOUS SLACK TIDE
(HOURS AFTER RELEASE)
X RELEASE POINT
NARROWS
BROOKLYN
STATEN ISLAND
CONEY ISLAND
ARTHUR KILL
NEW JERSEY
RARITAN RIVER
13.0
7.3
25.3
32.2
50.1
SANDY HOOK
NEW JERSEY
MILES
1 0 1 2 3 4 5

FIGURE 10

within the Bay, that:

(1) fresh water inflow from the Raritan River moves along the southern section of the Bay towards Sandy Hook; and

(2) particles introduced into the Bay at widely varying locales were eventually transported throughout the Bay with the finer particles gravitating toward the area bounded by Seguine Point and Great Kills, Staten Island, N. Y., and Keyport and Keansburg, N. J.

Project studies, as well as those performed by the U. S. Army Corps of Engineers on the Vicksburg model of New York Harbor, which have been reported previously by other agencies, indicated the complexity of the Raritan Bay system. Essentially the waters of Raritan Bay may be affected by materials discharged into waters outside the immediate limits of the study area. Hence, any effective control program for pollution control in Raritan Bay must consider the Bay not as an independent estuary, but as part of a larger interconnected system which includes Upper Bay, Kill Van Kull, Newark Bay, Arthur Kill and the Raritan River.

Recommendations for Remedial Action

On the basis of Project studies the following recommendations were made in order to reclaim study area waters for maximum beneficial uses:

1. Municipal treatment facilities should provide a minimum of 80% removal of BOD and suspended solids at all times, including any four hour period of the day when the strength of the raw wastes might be expected to exceed average conditions. Effective year round disinfection (effluent coliform count of no greater than one per ml in more than 10% of samples examined) at all municipal plants discharging directly to these waters shall be provided.

Unless existing orders specify earlier completion dates, in which case the earlier dates must be met, all improvements are to be completed by 1970.

2. Industrial plants shall improve practices for the segregation and treatment of wastes so as to effect maximum reduction of the following:

   a) Acids and alkalis

   b) Oil and tarry substances

   c) Phenolic and other compounds that contribute to taste, odor and tainting of fin and shellfish meat.

   d) Nutrient materials, including nitrogenous and phosphorous compounds.

   e) Suspended material

f) Toxic and highly colored wastes

g) Oxygen requiring substances

h) Heat

i) Foam producing discharges

j) Bacteria

k) Wastes which detract from optimum use and enjoyment of receiving waters.

Industrial treatment facilities, to accomplish such reduction, must provide removals at least the equivalent of those required for municipal treatment plants. Such facilities or reduction methods must be provided by 1970 unless existing orders specify earlier compliance dates, in which case the earlier dates must be met.

3. Facilities and procedures be established at each treatment facility to provide laboratory control.

4. State regulations be extended to require waste treatment facilities or holding tanks on all vessels and recreational boats using the area. If holding tanks are to be used, adequate dockside facilities should be required to ensure proper disposal of wastes.

5. Investigate additional proposals to safeguard water quality in the study area. These studies are to include, but not be limited to:

   a) Relocation of the main shipping channel through Raritan Bay to improve circulation characteristics;

b) Selection of areas for dredging for construction materials;

c) Suitable outfall locations for waste effluents to include possible trunk systems to divert effluents from the Arthur Kill.

Conferees, which include representatives from FWPCA, the States of New York and New Jersey, and the Interstate Sanitation Commission should meet every six months to review and initiate progress on the water quality improvements outlined above.

The authors wish to acknowledge the contributions of Mr. Paul De Falco, Jr., Regional Director, Southwest Region, FWPCA, who was the Project Director of the Raritan Bay Study, and Mr. Merrill S. Hohman, Director, Planning and Program Management, Northeast Region, FWPCA, who was Chief of Planning and Evaluation for this investigation.

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