REPORT

ON

STATUS OF POLLUTION OF THE RARITAN RIVER AND BAY

AND

EFFECT OF DISCHARGING INTO THE BAY TREATED MIXED EFFLUENTS

BY

DEPARTMENT OF SANITATION, RUTGERS UNIVERSITY

AND

DIVISION OF ENVIRONMENTAL SANITATION

N.J. STATE DEPARTMENT OF HEALTH

JANUARY 1951

LEGENDS TO FIGURES

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January 15, 1951

Mr. George F. Smith, Chairman
Middlesex County Sewerage Authority
New Brunswick, New Jersey

Dear Sir:

We submit herewith a report pertaining to surveys and studies on the status of pollution in the Raritan River and its tributaries in 1950, and the effect of discharging into the Bay of treated mixed effluents from a proposed treatment plant. The report has been divided into four general parts:

1. A historical review of pollution and pollution abatement in the Raritan River.

2. A condensed report pertaining to the surveys of the bay and river, municipal and industrial plant effluent, and bathing beaches located along the N. J. shore of the bay, studies on tidal and non-tidal currents, the effect of effluent discharges on water losses and salt water encroachment, and the relation of effluent discharges to shellfish in the bay.

3. A technical report giving in detail the results of the surveys and studies.

4. An appendix, consisting of data obtained, description of sampling stations and sampling and analytical procedures.

The historical review of the pollutional conditions and pollution abatement efforts during the last 25 years was included as a record of the deterioration of the river, to indicate the enormous amount of energy, time and money expended, and show the sequence of various efforts made to abate the pollution.

The condensed report was written to give a more or less general idea of the work done during the surveys and the conclusions reached from the data and information obtained without excessive detail.

The technical report and appendix contains the detailed results of the surveys, studies and investigations, together with discussions of the results and detailed conclusions reached.

If desired, we shall be glad to discuss the report with you or members of the authority at a mutually agreeable time.

Respectfully submitted,

Willem Rudolfs /s/
Chairman, Dept. of Sanitation,
Rutgers University.

Alfred H. Fletcher /s/
Director, Division of Environment
Sanitation, N.J. State Department
of Health.

A. HISTORICAL REVIEW

OF

POLLUTION AND POLLUTION ABATEMENT

RARITAN RIVER

During the past 25 years population increase and industrial development has been very rapid in the lower Raritan Valley. In 1926, the population in the lower valley was estimated to be about 175,000, whereas the 1950 census shows an approximate population for the same area of over 350,000. An increase of 100 percent in population demonstrates a healthy growth, but industrial expansion appears to have been far greater. On the basis of the organic wastes discharged by industry, the industrial population equivalent was estimated to be in 1926-27 about 85,000, whereas the waste produced in 1950 was equivalent to 750,000, or an increase of some 850 percent.

The Raritan River is the largest intra-state river system in New Jersey, comprising a drainage area of 1105 square miles. The Raritan is formed by the confluence of the North and South Branches. The principal tributaries are the Millstone River, Green Brook, Lawrence Brook and the South River. The river is subject to tidal effect for about 18 miles above its mouth. The population and industrial development is concentrated in the lower Raritan basin. Water from the Raritan River, Millstone River, Lawrence Brook and South River is used for potable and industrial supplies. The waters in the unpolluted state are soft and low in mineral content, which places them among the better waters of the United States for industrial use.

Deterioration of the River

In 1909, the State Board of Health recognized the pollution problem when it caused notice to be served upon mayor and common council of New Brunswick to cease pollution of the river before July 1, 1911. An advisory commission was formed which reported their findings to the mayor. Plans for a sewage treatment plant were approved by the State Board of Health in January 1911, but no plant was built.

Attention was called to the pollution of the river by Preble and Hoskins in 1915 in connection with possible contamination reaching the shellfish industries in the Raritan Bay and the importance of local nuisances below the discharge of sewers was stressed.

Seven years later, the pollution had increased to an extent that swimmers complained of disagreeable tastes and odors in the water and boats in the river were discolored by gases emanating from sludge banks and the wastes discharged into the river.

During a swimming meet of a group of girls, swimmers complaints of tastes and odors caused considerable adverse publicity and much comment among citizens about the disappearance of fish. Gradually the public became more and more aware of the undesirable conditions, frequently commented upon by members of the local boat and fishing clubs. The possibility that the Raritan would become a detriment rather than an asset to the municipalities, industries and citizens of the lower valley was recognized by a small group of public spirited citizens, among which Robert Wood Johnson of Johnson and Johnson at New Brunswick, and Warren King of King Chemical Company at Bound Brook were the leaders. Of particular interest is that two industrialists had not only the vision to restore and protect the river but actively worked to arouse public interest to save the river and bay. They were aided by others such as Russell E. Watson, New Brunswick attorney, who has had a prominent part in the various attempts to clean up the river. The group of people interested organized the Raritan Valley Conservation Association, in 1926 requested Rutgers University to cooperate with the association by instructing the Rutgers Department of Water Supply and Sewage disposal to make a preliminary survey of the degree and type of pollution of the Raritan River.

The results of the bacteriological preliminary survey showed that the river contained large numbers of colon bacilli, reaching the highest point below New Brunswick where the cumulative effect of all contributors was most evident. As a result of this preliminary survey, Mr. Richard J. Walsh was engaged to write a booklet, which was entitled "Save the Raritan". Mr. Walsh contrasted the "lost glories" of the Raritan when the water was suitable for drinking purposes, when shad was caught in large numbers, and when swimming and boating was enjoyed, with the existing conditions shown to be dangerous for swimming in the river anywhere from the town of Raritan to Perth Amboy.

Following the preliminary report, the Raritan Valley Conservation Association made an appeal to the Port Raritan

District Commission to appropriate a sum of $2500 to Rutgers University for a complete year's chemical and biological survey of the river and its tributaries. The Port Raritan District Commission, through its Chairman, Russell E. Watson, made an agreement with Rutgers University to conduct such a survey.

The objects of the study were to determine the nature and extent of pollution, the quantities of domestic and industrial wastes discharged and their effects upon the river in relation to public health and aquatic life, and collect data which could serve as a basis for improvement by remedial measures.

The conclusions reached from the survey were that the entire lower river and all of its tributaries were polluted, that pollution was additive, reaching its greatest concentration below New Brunswick before the river water is diluted with salt water, that there was a potential danger to public health in the whole lower river basis, that the pollution was injurious to fish life, especially during the summer months, that the pollution was detrimental to recreation, that the pollution already affected certain industries and with the expected growth in population and industrial activity there would be a considerable burden upon industries wishing to locate in the area, that odors and sludge bank formation were present which could be expected to be intensified in the future, and that pollution might interfere with navigation.

On the basis of the results, it was estimated that the raw sewage from about 150,000 people was augmented by a population equivalent of 85,000 people from industries.

Since no single municipality or single industry was responsible for the pollution, three possibilities for correction were given:

A. All wastes and sewage to be collected and discharged into the Ocean.

B. Construction of a trunk sewer with treatment by sedimentation.

C. Treatment in single or combined individual plants.

It was recommended that proper engineering surveys should be made to determine the economics of the different possibilities.

The Port Raritan District Commission obtained an appropriation of $15,000 from the legislature for a complete engineering study. The firm of Remmington, Vosbury and Goff of Camden, made a comprehensive field survey, studied the population growth, the flow of the river and investigated the collection and disposal of waste by means of a trunk sewer and by separate sewage treatment plants. The cost of a trunk sewer with a capacity of 175 mgd and a treatment plant with a submerged outfall in the Raritan Bay was estimated to be $15,000,000, whereas the cost of individual minicipal treatment plants was estimated to be $3,300,000. The latter figure did not take into consideration the cost of waste treatment by industries outside the municipal sewerage systems. It was concluded "that the construction of a trunk sewer should be postponed until such time that it may be required by an increase in the population served, that individual or joint plants be constructed by the several municipalities, and that industrial wastes be treated by the industries concerned."

The recommendations were placed before civic organizations, industrial representatives and municipal officials of the various cities and boroughs located along the Raritan River in the hope of developing and initiating by cooperative means either of the plans.

It soon became apparent to the State Department of Health that no progress was being made by voluntary cooperation. Accordingly, a request was made to the legislature for funds to enforce the law, and an item was included in the appropriation bill "To enforce the laws with respect to the pollution of the Raritan River - $25,000". The State Department of Health made independent surveys and upon the findings notices were issued to various municipalities commanding them to cease pollution and to dispose of the sewage in a manner satisfactory to the Department. A total of 17 notices were served.

Because of the depression most of the municipalities, already in financial difficulties, petitioned for an extension of time within which to comply with the terms of the notices. On February 2, 1932, the Department of Health granted a two year extension of time, provided each municipality admitted the allegations set forth by the Department, and agreed to enter a consent decree in the Court of Chancery. At the expiration of the two year period, the financial conditions of the municipalities had not improved and the terms not complied with.

In 1933, the Public Works Administration was created and financial assistance for sewage treatment projects was available, but only one municipality proceeded on its own initiative to apply and receive funds for construction of a plant. The failure of the other municipalities to apply for funds caused the State Department of Health to request the Attorney General to institute court proceedings, and on April 2, 1935 decrees were issued commanding the municipalities to cease pollution. To aid the N. J. State Department of Health in enforcing the laws, Mr. Russell B. Watson of New Brunswick, was assigned to it as Special Deputy Attorney General for the Raritan River projects. Forman (8) states Mr. Watsons' "interest, judgment and knowledge of the problems presented and counsel were frequently sought and graciously given".

Eventually all municipalities made application for loans and/or grants and constructed new plants or improved existing plants, which were placed in operation during the years 1937-39. It is clear that the municipalities elected to provide individual treatment plants rather than cooperate and construct a trunk sewer and combined treatment plant.

During the 10 years elapsed, the population in the Valley had increased and industrial development progressed rapidly. Before the new sewage treatment plants were placed into operation an opportunity was afforded to study actual conditions as compared with those a decade ago. Inasmuch as nowhere in this country scientific results on general pollution abatement on a whole stream, to which pollution was contributed from many municipal and industrial sources, where at that time available, the results were not only of local, but of state and national interest.

A survey conducted over a period of eleven months during May 1937 - March 1938, with help made available through a WPA project, showed that, in general, the bacterial pollution in the stream had decreased in the main river, but that the chemical condition of the river was poorer. The poorer chemical condition of the river was ascribed to the larger volumes of industrial wastes discharged. These chemical wastes interfered with the natural self-purification and oxidation power of the stream, was detrimental to fish life, and prevented the full recreational use of the river. The bacterial pollution was sufficiently high to make the river unfit for swimming.

Another survey was made during 1940-41. The results indicated a general bacterial improvement of the river as compared with previous surveys, except for a section around New Brunswick. The gross pollution, as indicated by oxygen demanding materials was, in general, lower than during a previous survey, except in a section of the river between Manville and Bound Brook where the population equivalent had increased from 107,000 to 171,200 people. These results checked with routine surveys made in the section of the river by the Calco Chemical Division, American Cyanamid Company.

Surveys made by the N. J. State Department of Health, which up to 1938 represented an expenditure of approximately $50,000 and consumed 3,900 man-days, showed that the raw sewage produced in the lower valley was equivalent to about 166,000 people, whereas the population equivalent of industrial wastes discharged without treatment amounted to about 439,000 people. Other data showed that some 146,000 pounds of mineral acids were discharged daily, in addition to toxic materials including arsenic, copper, lead, phenol, formaldehyde, benzaldehyde and other complex organic derivatives. By 1939, it was estimated that the domestic sewage treatment had reduced the pollutional load expressed in biochemical oxygen demand by 53.2%, the suspended solids by 71.1% and the coliform bacteria by 99.9%.

In 1940, when the sewage flow from municipal plants had increased to 26.8 million gallons daily, a total of 19 new and remodelled sewage treatment plants were in operation. A survey of the municipal sewage treatment plant efficiency conducted by the State Department of Health showed that the suspended solids removal averaged 80 percent and the removal of biochemical oxygen demand averaged 50.2 percent.

In the meantime, industrial expansion continued. This resulted in a corresponding increase in industrial wastes. In an attempt to ascertain the progress made in the pollution control project the N. J. State Department of Health made another survey during the summer of 1941. The survey indicated that the municipal treatment plants were functioning fairly satisfactorily, but that the increase in industrial wastes, caused by defense work, was "largely responsible for the inadequacies in plant capacity and equipment." Nevertheless, the Director of the State Department of Health, Dr. J. Lynn Mahaffey, could state that "notwithstanding the increased volume of polluting material discharged into the river, the pollution load has been reduced substantially below the level of 1937 by the treatment rendered by the plants in operation. Had these plants not been constructed, it may be confidently concluded that the river would have become a source of offensive odors, gravely jeopardizing the value of property along its banks, and seriously affecting the comfort of residents in its vicinity." Further, the improvement in the condition of the river "prevented irreparable injury to the shellfish industry."

From the surveys it became more and more evident that industrial wastes played an important role in the pollution of the river. Since all municipalities had constructed new sewage treatment plants or remodelled existing plants, the N. J. State Department of Health started renewed action against industries discharging untreated wastes into the river. Some 20 injunctions were obtained against concerns contaminating the river with their wastes, and all these industries were required to start studies of methods for abatement of pollution or construct treatment devices, and report their progress at stated intervals. Progress was made rather rapidly when World War II started.

As an aid in the further abatement and control of existing and future pollution, the State Department of Health in 1941 adopted standards based upon the quality and character of the sewage and industrial wastes discharged into the various sections of the river. The stream was divided into two zones, zone 1 comprising the river and tributaries extending from the confluence with the Millstone River to the Five-Mile (Enfield) dam or part of the river not subject to tide, and zone 2 the part of the river and its tributaries from the Five-Mile Dam to the Victory Bridge connecting Perth Amboy and South Amboy.

In 1935, an Interstate Sanitation Commission was created for the purpose of controlling the future and abating the existing pollution in the tidal and coastal waters of the adjacent portions of the signatory states of New Jersey, New York and Connecticut. The waters under jurisdiction of the Commission have been classified as A waters used primarily for recreational purposes, shellfish culture, and/or development of fish life, and B waters, where standards are less stringent. Jurisdiction of the Commission includes Raritan Bay and extends to the Victory Bridge crossing the Raritan River. These waters are designated as class A. This Commission has issued many citations or orders to municipalities within the district who are contributing pollution.

The World War interfered with progress in pollution abatement, but stimulated industrial expansion with an attended growth in population. Nevertheless, several industries constructed treatment plants or made intensive studies of their problems.

After the cessation of hostilities, the N. J. State Department of Health released a mimeographed summary and statement regarding the status of the Raritan River pollution control project. It informed the municipalities and industrial corporations concerned and the public regarding the status of each municipal and industrial waste treatment plant discharging into the lower Raritan River and South River. The summary noted that the pollution load on the Raritan and its tributaries had decreased somewhat despite the increase in industrial expansion. If the existing treatment plants had not been in operation the condition of the river would have been much worse. The Department of Health brought its investigation up to date and court action started in 1946. Various municipalities and industries made studies, employed engineers to design treatment plants or extensions to treatment plants.

Several of the larger industries had installed settling and/or neutralization devices. Progress continued, but was slow and by the spring of 1948 the Department of Health set the machinery in motion to compel offenders to alleviate the pollution. On the basis of a new survey made by the Department of Health during the summer of 1948, pressure was brought to bear on several municipalities and industries. All knew what the municipalities and industries were required to do. It was indicated that treatment of domestic sewage was comparatively easy and only a question of finances, but in the words of Russell E. Watson, special assistant attorney general, "Treatment of varied wastes from factories is a complicated problem. Each industry is a problem by itself. In treating industrial effluents we are at the beginning of a new science."

The magnitude and complexity of the problem was recognized by various agencies, municipal officials and industries and the question of a trunk sewer with a central sewage treatment plant was revived. In 1946, Commissioner Herbert D. Daily of New Brunswick raised the question that perhaps a trunk sewer was a better answer than building and extending individual treatment plants. In 1947, Freeholder Leon Campbell resurrected the idea, which was taken up by the Middlesex County Planning Board.

The State Department of Health had become convinced that the proper method for solving the problem was to construct a trunk sewer with a treatment plant of the combined wastes. However, it was not in favor of long drawn out studies of possibilities without final action.

The Planning Board under the leadership of its chairman, George F. Smith, instructed Elson T. Killam, Sanitary and Hydraulic Engineer to make a preliminary investigation to determine whether the policy involving individual treatment plants for municipalities and industries comprised the most economical and otherwise advantageous method of pollution control, or whether conditions, costs and future trends indicated that a complete investigation of alternative long range and comprehensive plans should be made.

The Killam report raised several questions, particularly in respect to the soundness of the trunk sewer proposal and the effect of the combined treatment plant on the waters of the Bay. The Middlesex Planning Board requested the Department of Sanitation of Rutgers University to conduct experiments to determine the characteristics and behavior of mixtures of domestic and industrial wastes and the feasibility of treatment of the mixtures, and engaged the engineering firm of Metcalf and Eddy of Boston to check the soundness of the proposal. Reports were rendered stating that the mixtures could be treated, and that the project was "sound from an engineering viewpoint," whereas separate treatment plants for municipalities and industries would not stop the pollution properly.

The Planning Board requested the Woods Hole Oceanic Institution, of Woods Hole, Mass., to make studies of the natural movement of water in Raritan Bay and indicate the effects of such movement upon dispersion of effluent from the proposed combined treatment plant. A report was rendered in June 1949.

The Planning Board then adopted a formal resolution recommending to the Middlesex County Freeholders the appointment of a Middlesex Sewerage Authority.

In the meantime, the N. J. State Department of Health held in abeyance any court action pending the outcome of the studies and investigations. Finally, the deadline was set by Dr. D. Bergsma, State Health Commissioner, for June 1, 1950 to appoint a Sewerage Authority or offenders would be prosecuted.

In August 1950, the State Department of Health announced new minimum requirements for the discharge of effluents in the previously established two zones of the Raritan. In announcing the new requirements, the State Department of Health released a statement which reads in part "In accordance with its policy of aiding citizens of this state in the promotion of public health and facilities designed to protect the public health, - - - - domestic sewage and industrial wastes produced in the lower Raritan Valley should be collected and transmitted down the valley by means of a trunk sewer with satisfactory treatment and disposal in a larger body of dilution water ."

The Board of Chosen Freeholders created a Middlesex County Sewerage Authority, the members of which were sworn in on July 28, 1950 at the County Court House. The Sewerage Authority was formally organized on August 1, 1950 and began work by requesting the engineering firms of Metcalf and Eddy and Elson T. Killam to prepare a report embodying methods of cost allocation and development of formula for equitable charging costs to municipalities and industries.

The Sewerage Authority requested the Department of Sanitation of Rutgers University and the Division of Environmental Sanitation of the State Department of Health to conduct surveys to determine the present pollution conditions of the Raritan River and its tributaries and in the Raritan Bay, and determine the effect of discharging into the Bay treated mixed effluents. The attached report is the result of these studies.

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B. CONDENSED REPORT

ON

STATUS OF POLLUTION OF THE RARITAN RIVER AND BAY

AND

EFFECT OF DISCHARGING INTO THE BAY TREATED MIXED EFFLUENTS

Extensive chemical and bacteriological surveys were made during July and August 1950 for the purpose of determining the status of pollution of the Raritan River and its tributaries as well as of the upper Bay and Arthur Kill. Surveys were also made to determine the character and quantities of pollutional matter produced by various municipalities and industries and the efficiency of existing municipal and industrial wastes treatment plants. Further, surveys were made of the surf waters at bathing beaches in the bay. Studies were made of the tidal and non-tidal currents to estimate the probable effect of discharging treated mixed effluents in relation to pollution of beaches and shellfish areas, and calculations were made regarding water losses in the river by the construction of a trunk sewer and the possible salt encroachment in the fresh water well field adjacent to the River.

In order to enable the reader to have a comprehensive picture the mass of data obtained during the surveys are presented in condensed form. To facilitate reading and aid in ready reference to specific topics the various phases of the investigation are presented under the following general headings:

1. Bay Survey,
2. River Survey (tidal and non-tidal section),
3. Municipal and industrial waste survey, (quantities and character of wastes, performance of plants, and estimated relative contributions to a trunk sewer),
4. Tidal and non-tidal currents (indicating the behavior of fresh and salt water and pollution distribution),
5. Beach survey,
6. Pollution in relation to shellfish,
7. Water losses and salt water encroachment.

Extent of Survey

During the survey a total of 3256 samples were taken in the bay, the Raritan River and its tributaries, of municipal and industrial effluents, and in surf waters of the bathing beaches along the New Jersey shore of the bay. A total of 7087 bacteriological and chemical analyses were made on the samples collected.

Results

Sampling station locations in the river and bay were selected to show existing conditions. In the tidal section of the river and in the bay, samples were collected during incoming and outgoing tide cycles. Samples of municipal and industrial waste effluents were collected over periods of a number of hours and in some instances results obtained over extended periods were utilized. Analyses included bacteriological (coliform organisms), dissolved oxygen (D.O.), biochemical oxygen demand (B.O.D.) and various other chemical analyses. All analyses were made in accordance to "Standard Methods for Examination of Water and Sewage."

I. Bay Survey

For the purpose of determining the pollution conditions in the Raritan Bay during July and August 1950, a section of the upper bay was divided into a grid section with fifteen sampling stations. The average chemical and bacteriological results, indicating organic and bacterial pollution, obtained with samples taken at the top and bottom and at high and low tide water of the bay, in the mouth of the Raritan, in the Arthur Kill, and of water in the bay near the mouth of the Arthur Kill were as follows, expressed in parts per million (ppm), biochemical oxygen demand (B.O.D.), percentage saturation of dissolved oxygen (D.O.), and most probably numbers (MPN) of coliform organisms per milliliter (m.l.).

	BOD ppm	D.O. % Sat.	Coliforms MPN/ml.
Bay	2.2	78	44
Mouth of Raritan	1.7	61	111
Near mouth of Arthur Kill	1.5	65	77
Arthur Kill	2.9	63	14

The organic pollution in the upper bay, is low and does not present a problem in respect to the dissolved oxygen balance, and will therefore not effect fish life or result in odor nuisances.

The bacterial pollution in the bay is relatively high, with the highest numbers of organisms near the mouth of the Raritan River. The bacterial pollution extends like a tongue into the Bay with the highest numbers near the center of the tongue.

In general, the condition of the bay is poorest near the surface of the water at low tide.

The pollution of the Arthur Kill is primarily organic in nature, being higher than in the upper bay or at the mouth of the Raritan. The bacterial pollution in the Arthur Kill is less than in the bay or the mouth of the Raritan.

Conclusions

1. The organic pollution in the bay presents no problem, because of dilution and self-purification forces at work.

2. The bacterial pollution in the bay is relatively high and originates primarily in the Raritan River.

3. The pollution of the Arthur Kill has a deleterious effect on the waters of the bay.

II. River Survey

For a determination of the existing pollution of the Raritan River and its tributaries series of samples were collected in the tidal and non-tidal section of the river and its tributaries. Because of the dilution and tidal effects, the results obtained have been assembled and discussed in two parts:

a. Tidal Section.

The tidal section of the river surveyed is the stretch of river between the Enfield (5 mile) dam and the Victory Bridge, and includes the South River.

The average chemical and bacteriological results obtained from samples taken at the surface and near the bottom during incoming and outgoing tides showed that the dissolved oxygen in the river just below New Brunswick was extremely low (near zero oxygen saturation) and the coliform content exceedingly high (average 62,000 coliforms per ml.). At this point, the river reached its lowest state of degradation as the result of cumulative pollution from upstream in addition to that contributed by New Brunswick. The existing sludge deposits affect the river and is partly the cause of the poor condition of the river below New Brunswick. The sludge deposits are a contributary factor to odors from the river.

The pollution was not confined to a local area but extended for a considerable distance downstream. For a distance of about one mile, the poor conditions remained about the same, but with increased dilution with salt water and natural self-purification, the pollution showed an apparent decrease until at the Victory Bridge the dissolved oxygen saturation was increased to an average of 51.5 percent and the coliform organisms decreased to 440 per milliliter.

The organic pollution in the South River at Old Bridge was worse than anywhere else in the Raritan River or other tributaries.

b. Non-tidal Section.

The non-tidal section of the river surveyed is that part of the river from the North Branch to the Enfield (5 mile) Dam and includes the tributaries- Millstone River and Greenbrook.

Results of the survey show that the North Branch and Millstone River were in good consition, but the Greenbrook had only 25 percent oxygen saturation with an average coliform content of 104 per ml. The progressive organic and bacterial pollution in the river is illustrated by the following results: Pollution increased from the North Branch to Finderne, the average dissolved oxygen dropping from 83 percent to 79 percent and the coliform organisms increasing from 13 to 460 per milliliter. From Finderne to Bound Brook the dissolved oxygen saturation decreased further to 27 percent, with a corresponding increase in biochemical oxygen demand from 1.6 to 42 parts per million, but the numbers of coliform organisms decreased from 460 to 190 per milliliter. From Bound Brook to Landing Bridge the dissolved oxygen saturation increased slightly to 31 percent and the B.O.D. decreased to 35 ppm, but the coliform organisms increased greatly to 3500 per ml.

c. Sources of pollution.

The pollution in the river is caused by the effluents discharged by the municipalities and industries located in the lower Raritan River basin. It is the result of the cumulative quantities of wastes. During the survey the total effluent flows recorded amounted to 103 million gallons daily, of which 36.5 mgd was contributed by municipalities and 63.5 mgd by industries. The actual pollutional load, expressed in pounds of biochemical oxygen demand and the calculated population equivalents, together with the percentages contributed by municipalities and industries was as follows:

	Flow		B.O.D.		Pop. Equivalent	
	mgd	%	lbs.	%	No.	%
Municipalities	37.47	36.5	43,485	34	262,910	34.4
Industries	65.5	63.5	83,760	66	502,550	65.6
Total	100.3	100	127,245	100	765,460	100

Considerable amounts of industrial wastes are treated by municipal plants, but no effort was made to determine the quantities or characteristics of such wastes, because wastes discharged into municipal sewers are considered to be the responsibilities of the various municipalities.

The pollution of the river has gradually increased over the years. As an illustration of this increase, the population equivalents of the pollution in the river at Bound Brook, which has been determined by a number of surveys, is of interest. These calculations were made possible because the flows for that part of the river are recorded. The increase in pollution, shown as population equivalents, which means the equivalent of raw sewage discharged by those numbers of persons, were as follows:

Year	Pop. Equivalent
1927 - 28	88,200
1937 - 38	107,000
1940 - 41	171,200
1950	238,000

In other words, the pollution in the river at Bound Brook increased about 365 percent from 1927 - 28 to 1950, despite the construction and operation of municipal and industrial wastes treatment plants. What would have happened without the minicipal and industrial wastes treatment plants must be left to conjecture.

The population increase and industrial expansion during the two decades has been extensive, not only in the non-tidal section of the river, but also in the tidal section, resulting in the progressive deterioration and degradation of the river.

Conclusions

1. The Raritan River pollution increases progressively downstream and reaches a maximum concentration below New Brunswick. Below this point the pollution concentration decreases because

of dilution with salt water and self-purification of the stream.

2. The North Branch and Millstone Rivers are in good condition. Greenbrook shows some pollution and the South River at Old Bridge is in a worse condition than the Raritan River at any point.

3. The existing organic pollution in the river is equivalent to the raw sewage discharged by more than 765,000 people, of which about 34 percent is contributed by municipal and 66 percent by industrial effluents.

4. Despite construction and operation of municipal and industrial wastes treatment plants the pollution of the river has increased greatly during the period 1927/28 - 1950 resulting in progressive degradation of the river.

III. Municipal and Industrial Effluents Survey

A survey was made of municipal and industrial treatment plants and untreated effluents discharged by industries to determine existing conditions, the performance of the plants, and the relative contributions each municipality and each industry may make to the proposed trunk sewer.

A total of 1260 samples were taken and about 2830 analyses made.

a. Performance of Plants.

Sewage treatment plants are designed to produce certain degrees of purification. Of the 22 minicipal plants surveyed

12 did not perform in accordance with expectations.

The sewage and industrial waste effluents are required to meet certain standards promulgated by the N. J. State Department of Health. Some of the requirements are concerned with suspended solids, B.O.D. and coliform organisms. Of the 22 minicipal plants surveyed 16 did not meet the present requirements in respect to suspended solids, B.O.D. and/or coliform organisms. Of the 16 industrial effluents surveyed 11 did not meet the requirements in respect to B.O.D. and/or coliform organisms. For industrial wastes, other criteria, pertaining to turbidity, color, oil, sleek, taste, odor, alkalinity, acidity and poisons, are considered. Using any or all of these criteria possibly two industries with small volumes of effluents would meet all requirements.

b. Relative Contributions.

The relative contributions of each municipality and each industry to a proposed trunk sewer were calculated upon the basis of surveys and records obtained. In the case of industries discharging appreciable quantities of cooling waters it was assumed that most of these cooling waters would be discharged direct to the river.

Since the volumes of waste, sludge forming constituents (suspended solids) and B.O.D. of the wastes may be considered as most important in respect to the handling, treatment and disposal of the waste, these three criteria were used in calculating the contributions of the municipalities and industries.

The totals and percentages were found to be as follows:

	Total	Municipalities	Industries
Flow, mg.	76	42.5	57.5
Suspended Solids, lbs.	197,440	43.0	57.0
B.O.D., lbs.	185,340	52.5	47.5
Pop. Equivalents	1,111,400	52.5	47.5

The dry suspended solids production of some 197,500 lbs. would amount, on the basis of an average of 10 percent solids, to nearly 1000 tons wet sludge a day. This quantity of sludge indicates the magnitude of the sludge disposal problem.

The total population equivalent of all wastes are calculated to be about 1,112,000 with about 583,000 produced by municipalities. Considering that the entire population of the lower valley draining to the Raritan is estimated at about 350,000 it is evident that a considerable part of the organic pollution produced by municipalities is caused by industrial wastes discharged into municipal sewers.

Conclusions

1. Most of the effluents discharged by municipalities and industries do not meet present requirements.

2. Industrial effluents, not discharged into municipal sewers, contribute a larger volume and less sludge forming matter than the sewage from municipalities.

3. It appears that the municipal wastes contain over 40 percent organic pollutional matter of industrial origin.

IV. Tidal and Non-Tidal Currents

The chemical and bacteriological results obtained in the bay were plotted on a series of maps to indicate pollution densities and variations in the condition of the bay. The plotted results were used to show the behavior of tidal and non-tidal currents which allowed calculations to be made concerning the behavior and effect of effluent from a treatment plant discharged at the approximate proposed location in the bay.

The fresh water of the river, as illustrated by Figs. 8-15 continues to move as a body for a considerable distance into the bay, with the result that the major portion of the river flow protrudes straight out into the bay, keeping on the New Jersey side with the center of the flow about 6,000 feet off-shore. The movement of bottom water is less pronounced; this is probably the result of difference in density or salt content of the fresh and salt water, which allows the fresh water to ride over the salt water.

The bottom water veers to the north-east in the direction of the deep channel because the deeper channel has a tendency to guide the fresh water. During outgoing tide the velocity of the fresh water gradually increases and the veering of the fresh water is more pronounced. The Cheesequake Creek exerts also its influence in pushing the fresh water stream to the center of the bay.

Measurements and calculations from the chemical analyses, particularly the iron content, show a seaward movement of water on the ebb tide, averaging about 3,500 to 3,600 feet per hour.

On the basis of various calculations it appears that the river at ebb tide has a maximum seaward velocity of 5,000 feet per hour at the mouth of the river and about 2,000 feet per hour four miles out in the bay.

Calculations of the average non-tidal water excursion and the non-tidal sea water drift show that it takes about 11.5 days for fresh water to move 10,500 feet from the mouth of the river to the two mile point proposed for the discharge of effluent from a treatment plant. The non-tidal landward drift of sea-water takes more than 30 days for bay water to move backward from the two-mile point to the mouth of the river.

The tidal movement of water is greater than the non-tidal. The average tidal excursion velocity appears to be approximately 800 feet per hour, whereas the seaward movement of non-tidal water is about 40 feet per hour and the landward movement about 10 feet per hour.

The velocities of the outflowing river water are from six times the average excursion velocity at the mouth of the river to twice the tidal excursion velocity at the two mile point. This means that even with incoming tide, a portion of the river water flow continues seaward.

The total or net movement of water across the bay is backward on the flood tide. Since the center portion of the water continues forward, the bay water near the shores moves backward faster than the tidal excursion. In other words, during the flood tide the fresh water protrudes like the point of an arrow into the bay causing the water near the shores to flow backward.

The outward moving fresh water mixes gradually with the bay water and the mixture of fresh and salt water requires a number of days before it again moves towards the mouth of the river. The great dilution of fresh with salt water, together with the self-purification of the water, results in greatly decreased organic pollution. In addition, the salt water reduces the number of coliform organisms.

Calculations show that if a sewer outfall, discharging 100 mil. gals. a day is located at the proposed two mile point in the bay, the maximum effluent concentration at the head of the bay (Amboy's Area) would amount to two percent of the total water. Under these conditions it would require 30 days for the polluted water to reach the Amboy's Area. Under average conditions of river flow the concentration would amount to 1 percent. Hence, location of an outfall at the two mile point would greatly reduce the pollution in the Amboy's area, even if the mixed sewage and wastes were not treated, because self-purification over a period of 30 days required for the mixed water to return would result in at least 90 percent reduction in organic and bacterial pollution. Since it is proposed to treat the wastes the numbers of intestinal bacteria and amounts of organic solids would be reduced as compared with present conditions, tending to reduce the remaining pollution concentration still further.

Because the river forces itself a considerable distance into the bay, the proposed site of treated effluent discharge should be chosen to take maximum advantage of the natural seaward currents and reduce the landward movement of the salt water-effluent mixtures.

Conclusions

1. The major portion of the river flow protrudes straight out into the bay with the center about 6,000 feet off-shore. Part of the river flow, particularly that near the bottom, veers northward towards the ship channel.'

2. Because of the behavior of the currents and concurrent self-purification, the condition of the upper bay is better than might be expected from the pollution in the river.

3. For the location of an outfall for treated waste effluents advantage should be taken of desirable seaward currents and velocities to carry the treated effluent farther into the bay for dispersion with large bodies of water and to reduce the possibility of landward movement of the salt water-effluent mixtures.

4. With proper location of the outfall and discharge of treated effluent the amount of effluent which could return to the head of the bay would be negligible and materially improve existing conditions along the shores.

V. Beach Survey

The bacteriological studies on coliform organisms present in surf samples at the Raritan Bay beaches show that the average number of coliform organisms found varied from 1.1 to 74.6 at different beaches. The lowest numbers of coliform organisms were found in the surf samples at Union Beach (Pine Street) and Keansburg (Lawrence Ave.) beach. The highest numbers of coliform organisms were found at Cliffwood beach and Perth Amboy (State Street) beach. The latter two beaches did not meet the tentative working standards used by the N. J. State Department of Health.

The average coliform results obtained in the bay survey show that the greatest density of organisms extend as a tongue from the mouth of the river, with the highest concentration in the center of the tongue and with considerably lower numbers in the water nearer the shore. At the edges of the tongue nearest to the New Jersey shore the coliform density was 16 per milliliter.

It is conceivable that a portion of the pollution found in the surf samples at the beaches is the result of the pollution in the river, but the high numbers of organisms found in the surf samples of some of the beaches point in the direction of local pollution.

The removal of pollution from the river and discharge of treated effluent about 2 miles out in the bay will reduce the pollution of the beaches in the upper bay area so that beach pollution would be primarily affected by local conditions.

Conclusions

1. The average number of coliform organisms found in the surf samples of two beaches out of 22 surveyed were higher than

the tentative working standards of the N. J. State Department of Health allow for beaches suitable for bathing purposes.

2. The bacterial pollution of a number of surf waters appears to be partly of local origin and partly caused by the pollution of the Raritan River and other tributaries to the bay.

3. Removal of bacterial pollution from the river and discharge of treated effluent about 2 miles in the bay will reduce pollution of the beaches in the upper bay.

VI. Pollution in Relation to Shellfish

Most of the area in Raritan Bay is closed to the taking of shellfish because of bacterial pollution in the water. The major sources of pollution in the shellfish areas are Raritan River, Arthur Kill, shore pollution (Staten Island and New Jersey) and Lower New York Bay (through the narrows, Rockaway Inlet, etc.).

Study of the coliform data obtained in the Bay indicates that the bacterial pollution of the upper Raritan Bay is influenced by the pollution in the Raritan River and Arthur Kill, whereas the pollution of the lower Raritan Bay is influenced by pollution contributed from Lower New York Bay, and that the pollution along the shore bounding the open shellfish areas is contributed by bordering shore communities.

The coliform bacterial standards set by the U. S. Public Health Service for shellfish taking is 0.7 per ml. The studies made during the summer of 1950 show that the average number of coliform about one mile from the edge of the open shellfish area averaged about 20 per ml.

The bacterial pollution of the Raritan Bay area surveyed has shown a rapid increase during the last 10 years, whereas during the preceeding 30 years (1912-1940) the condition remained practically static. It is of considerable interest in this respect, that the volumes of wastes discharged since 1940 have increased materially, whereas the treatment of the wastes did not increase proportionally.

The fact that certain areas of the Bay are still open for shell fishing may be explained by the following:

1. The influence of the Raritan River on coliform levels in the Bay extend about 4 miles out. Beyond this point sufficient dilution has occurred and the bacterial death rate has been high enough to make the open area satisfactory for clamming.

2. Previous to 1940 the coliform bacteria counts were greatly influenced by the pollution in New York Bay and Long Island areas, which has considerably improved because of sewage facilities provided.

If all the sewage and industrial waste in the lower Raritan Valley is treated in the proposed treatment plant and the effluent discharged approximately 2 miles out in the Bay, it may be expected that the offshore area of the upper Raritan Bay will be opened to shellfishing because: (1) The major source of coliform organisms in the upper Bay would be eliminated, and (2) the effluent discharged would have a coliform bacteria content approximately that of the shellfishing standards.

On the assumption that bacterial pollution entering Arthur Kill and other areas under jurisdiction of the Inter-state Sanitation Commission will be largely eliminated in the future, the bacterial condition of the Bay will be further improved.

The shore areas of the upper Raritan Bay will probably remain closed to shellfishing unless the local shore communities eliminate the discharge of ineffectively treated wastes.

The areas closed to shellfishing in the lower Raritan Bay, which are greatly affected by pollution originating in New York and which are not materially affected by the Raritan River pollution, will remain closed until the New York City Sewage treatment program has farther advanced and the New York shore communities have solved their sewage pollution problems.

Conclusions

Construction of a trunk sewer along the river and treatment plant outfall at approximately 2 miles out in the bay will result in:

1. Improving greatly the bacterial conditions of the upper bay area now closed for shellfish taking,

2. Aiding the opening of an increased area for shellfish taking in the upper bay,

3. Affecting only to a minor degree the opening of the shellfish area in the lower Bay.

VII. Water Losses and Salt Water Encroachment

a. Water Losses.

When a trunk sewer and treatment plant is constructed with a proper distribution outfall about two miles into the Raritan Bay, a part of the river flow, consisting of municipal and industrial effluents, will be taken out of the river. What effect will the removal of effluents have on the volume of the river, and how much will it increase the salt concentration in the lower section of the river? Increased salinity in the tidal section of the river may conceivably affect the salt encroachment in the fresh water well fields adjacent to the river.

The question of water loss may be divided into two parts: (1) the effect on the upper section of the river from the North Branch to the Enfield (5-mile) Dam, and (2) the tidal zone from the 5-mile dam to the mouth of the bay.

The average daily flow in the river for each year recorded by the U.S. Geological Survey varied during the last 20 years from 745 to 1450 million gallons a day, with the lowest average flow per day for any month of 195 mil. gallons a day, occurring during the fall.

The estimated total domestic and industrial waste flow is about 100 mil. gals. a day of which 42 mil. gals. a day is cooling water.

The known sources of water used for domestic and industrial purposes are 34 mgd from surface supplies, 33 mgd from wells, and 32 mgd direct from the Raritan (cooling waters, etc.).

1. Upper Zone. The total estimated waste flow discharged into the upper zone is about 32 mgd, of which about 12 mgd is cooling water. The average daily flow in the river at Bound Brook for any year since 1923 varied from 650 to 1340 mgd with the lowest average daily flow for any month ever reported of 130 mgd. Since it may be assumed that most, if not all, of the cooling waters would be discharged direct to the river the reduction in flow would amount to 20 mgd, which based upon the lowest average river flow, would amount to about 8 percent of the river flow and during the lowest average flow for any month reported amount to 15.4 percent.

The Raritan River is a so called "flashy" river, with flows varying materially after every rain. With the waste effluents taken out of the river and the water restored to conditions prevailing in the river above Raritan Borough and in the Millstone River, it is doubtful whether the reduction in the river would be noticeable.

2. Tidal Zone. The total accumulative flow of effluents in the tidal zone constitutes about 100 mgd of which 42 mgd are cooling waters. Recent information and studies conducted by the Woods Hole Oceanic Institute during a dry period show that the river flow entering the bay amounted to 375 mgd. If the total waste effluent flow amounted to as much as one-third (125 mgd) of the entire river, the volume of waste effluents would represent from 3 to 5 percent of the tidal water. If the waste effluents taken out of the

river amounted to 65 mgd, it would amount to about 1.5 to 2.5 percent of the tidal water. Such a small reduction would not be noticeable even if the "fresh" water were not replaced by bay water.

b. Salt Water Encroachment

The removal of effluents from the river and their discharge into the bay may affect the salinity in the water of the tidal section of the river. Theoretically, any increase in the salinity may affect the ground water supplies adjacent to the river.

Assuming extreme conditions, namely the lowest average daily river flow of 130 mgd for any month recorded at Bound Brook and not considering additional fresh water from tributaries below Bound Brook, and assuming that 65 mgd of waste effluents were taken out of the river and piped to sea so that it would constitute an absolute loss, the waste effluent would constitute about 0.5 to 1.0 percent of the water in the tidal zone of the river.

During the 1950 survey the salt concentration in the tidal zone and Washington Canal was determined at low and high tides. At high tide when the danger of salt encroachment would be greatest, the maximum chloride content in the Washington Canal was 10,700 parts per million. If 65 mgd of the waste effluents were taken out the maximum salt concentration in terms of chlorides would increase from 10,700 to about 10,800 parts per million during the lowest daily flow of any month recorded. If all the effluents (100 mgd) were removed from the river and the diversion amounted to as much as 5 percent of the water in the tidal zone, the salt concentration would increase from a maximum recorded 10,700 ppm to 11,235 ppm at high tide. It is doubtful that such a minor increase in the salinity at any given time in the Washington Canal would have any appreciable effect on the adjacent fresh water well field or constitute a potential danger.

A report made by Dr. Bostwick H. Ketchum of the Woods Hole Oceanic Institute states that: "At the mouth of the River there is very little difference in salinity as a result of diverting some of the river water in a trunk sewer. At this point the minimum river flow may be expected to produce a salinity of 25.6 o/oo; complete removal of 100 mgd would produce a salinity of 26.5 o/oo; reintroduction of the effluent into the Bay a mile and a half from South Amboy would produce a salinity of 25.3 o/oo. At the mouth of the Washington Canal (6 miles from river mouth) the corresponding salinities would be 20 o/oo for minimum river flow; 24.5 o/oo for the complete removal of effluent; and 23.6 o/oo for the reintroduced effluent. It should be emphasized that the salinities quoted above are for the high tide conditions which would produce, at any given location, maximum salinities during the tidal cycle. Since the calculations were made for minimum river flow they are also maximum salinities to be expected during the year."

Conclusions

1. Collection of all waste effluents into a trunk sewer would reduce the river flow above 5-mile dam about 15 percent during the driest period of the year, and would not noticeably affect the volume of water in the tidal zone of the river.

2. Collection of all waste effluents into a trunk sewer and discharge of treated effluent in the bay may increase the salt concentration in the Washington Canal at high tide and lowest river flow by a maximum of 5 percent.

3. It is doubtful whether the loss of water or increase in salinity would be noticeable.

APPENDIX

EXPLANATION OF CERTAIN TERMS USED IN THE REPORT

Biochemical Oxygen Demand (B.O.D.)

A measure of the amount of decomposable organic material in the water. Actually the amount of oxygen used by the bacteria in 5 days while decomposing the organic material at a temperature of 68° Farenheit.

Dissolved Oxygen (D.O.)

The amount of oxygen dissolved in the water. The source of oxygen for fish and other water animals and bacteria which require oxygen to live. The maximum amount which can dissolve under ordinary summer temperatures is very small, 8 parts in 1,000,000 parts of water (8 parts per million).

Part per Million (ppm)

A unit of measure convenient for expressing the amounts of material found in water. One part in one million parts of water is equivalent to 8 pounds of material in 1,000,000 gallons of water.

Suspended Solids

The material in the water, which can be removed by filtering through a fine mat. Essentially all of the material which makes the water cloudy or turbid.

Turbidity

A measure of the cloudiness of the water, as it appears to the eye. Essentially, a measure of the suspended solids.

Used principally with waters containing very small amounts of fine suspended material amounting to a few parts per million.

Tidal Current

A varying water current or flow caused by the rising and falling of the tide.

Non-Tidal Current

A theoretical uniform water movement within a tidal body of water, such as a bay or river. Usually applied to the theoretical movement of fresh river water toward the ocean or the movement of salt ocean water toward the land.

ml (Milliliter)

A volume equal to 1 cubic centimeter or about 15 drops of water.

Coliforms (B. coli; E. coli)

A group of easily identified bacteria which are used as an indication of pollution because they are found in great abundance in the intestinal tract of man and animals.

M.P.N. (Most Probable Number)

The number of bacteria in a given volume of water as calculated by statistical methods from a set of analytical results.

Percent Saturation

The ratio of the dissolved oxygen in the water to the maximum possible dissolved oxygen content under the same conditions of temperature, pressure, and salinity.

Upper Bay (Head of Bay)

The area of the bay near the mouth of the chief tributary river. The part away from the ocean.

Salinity

The total dissolved salt content of the water.

Chlorides

A part of a dissolved salt particularly found in sea water (sodium chloride - common table salt). The chloride concentration is used as an index of the sea water concentration since sea water contains approximately 20,000 ppm chlorides.

Iron

The concentration of dissolved or suspended iron salts or compounds in the water expressed on the basis of their iron content.

C. TECHNICAL REPORT

ON

STATUS OF POLLUTION OF RARITAN RIVER AND BAY IN 1950

AND

EFFECT OF DISCHARGING INTO THE BAY TREATED MIXED EFFLUENTS

I. Introduction

During the last two decades a number of surveys concerning the pollutional conditions of the Raritan River and its tributaries, and to a less extent of the Raritan Bay, have been made. Despite extensive efforts and expenditures of large sums of money the pollution gradually increased because of the rapid population increase and expansion of industry.

The magnitude and complexity of the pollution problem has been recognized by various agencies, municipal officers and industries. The Middlesex Sewerage Authority desired to have a comprehensive study made as a basis for deliberation, discussion and action. The Sewerage Authority requested the Department of Sanitation of Rutgers University and the Division of Environmental Sanitation of the N. J. State Department of Health to jointly conduct these investigations and studies.

a. Purpose of Studies

The specific purposes of the surveys and studies may be summarized as follows:

1. To determine the actual status of bacterial and organic pollution of the Raritan River, its tributaries and of

the Bay.

2. To determine the type and quantities of pollutional matter contributed by municipalities and by those industries discharging effluents directly to the river or its tributaries.

3. To determine the efficiency of existing sewage and industrial waste treatment plants in respect to meeting the existing requirements of the N. J. State Department of Health.

4. Estimation of the probable effect of discharging treated mixed waste effluents about two miles out in the Bay in respect to the existing beaches, oyster grounds, the behavior of tidal and non-tidal currents in respect to movement of treated effluent, the water losses from the river and the possible salt water encroachment of the fresh water well fields adjacent to the river.

b. Extent of Survey

The survey made was more comprehensive and more extensive than any previous survey made. This is examplified by the fact that the number of samples taken amounted to 3256 and the number of chemical and bacteriological analyses made was 7087, divided as follows:

	Samples	Analyses
River and tributaries	540	1265
Bay	1280	2816
Beaches	176	176

Municipal Sewage	660	1430
Industrial Wastes	600	1400
Total	3256	7087

Report

The report consists of four parts:

A. Historical Review.

B. A condensed report showing the summarized results obtained and giving the general conclusions drawn from the studies, analyses and calculations.

C. A technical part, containing results, graphs, charts, calculations and discussions pertaining to the various phases of the survey.

D. An appendix, including the detailed methods and procedures of the survey, and the individual or averaged results obtained in tabular form.

II. Bay Survey

During July and August 1950, a survey of the Raritan Bay was made to determine the existing pollution conditions.

A section of the upper bay was divided into a grid pattern with fifteen sampling stations. The location and depth of the sampling stations are indicated by numbers in Figure 1. To determine the influence of the Arthur Kill on the pollution of the bay, a sampling station was located in the Arthur Kill.

At each sampling station, eight samples were taken; four at low tide and four at high tide. During each sampling period one sample was taken from the surface and another about two feet from the bottom. The total number of samples taken was 1280.

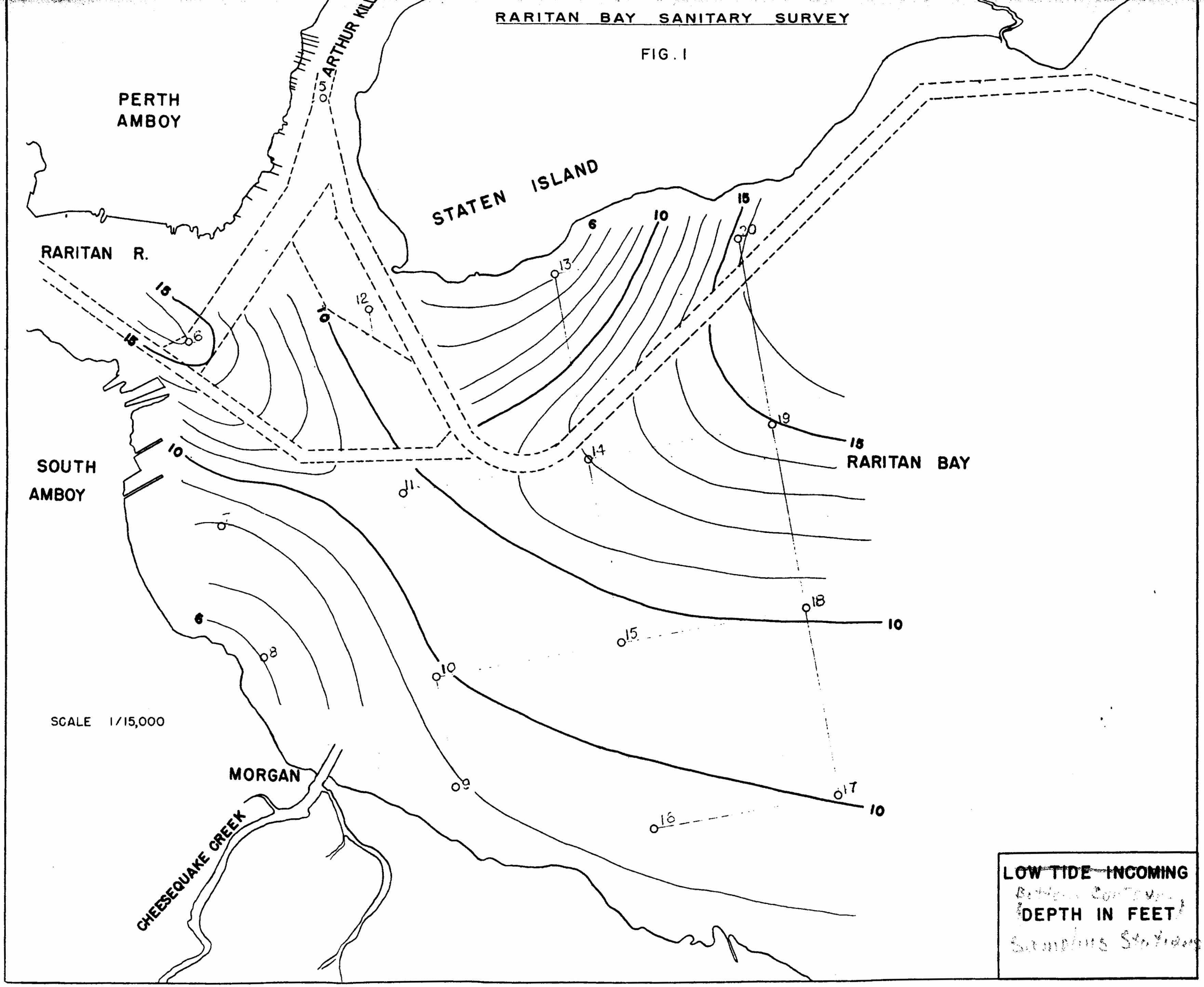
Analyses made on the water samples included temperature, dissolved oxygen determination, pH, chlorides, acidity, alkalinity, turbidity, total iron, biochemical oxygen demand (BOD) and coliform organisms. The dissolved oxygen determinations were made immediately on the boat up to the point of titration. Coliform samples were taken in sterile bottles and refrigerated immediately. The number of analyses made was 2816. All analyses were made according to the procedures in the "Standard Methods of Examination of Water and Sewage, 9th Edition."

a. Results

The results of the analysis for each sampling period are shown in Tables A to H in the appendix. The average

RARITAN BAY SANITARY SURVEY

FIG. I



percentage dissolved oxygen saturation, B.O.D., chlorides,iron and coliform organisms for high and low tides for each station is given in Table 1. The condition of pollution of the bay at the time of the survey can be assessed by the various determinations, especially by the coliform organisms, D.O. and B.O.D.

With few exceptions the percentage dissolved oxygen saturation in the bottom samples both at high and low tides was lower than in the surface samples. The exceptions are station 8 (near Morgan) at high and low tides, and station 7 (near South Amboy) at high tide. The high tide values for both surface and bottom samples were invariably higher for all sampling stations. At several stations, supersaturation values were obtained at high tides, particularly at stations 17, 16 and in top and bottom samples. These were all stations located near the New Jersey shore in comparatively shallow waters. The minimum dissolved oxygen (D.O.) saturation in top and bottom samples at low tide occurred at station 6 near Perth Amboy with 61 and 53 percent respectively. At high tide the minimum D.O. saturation, both in top and bottom samples, occurred at the same station with 67 and 65 percent respectively. Other samples with low D.O. values were those from station 5 (Arthur Kill) with 62 percent in the top and 52 percent in the bottom during incoming tide, and at station 12 (near the southern tip of Staten Island) at low tide with 60 percent in the top and 54 percent in the bottom samples.

TABLE 1

The Average Chemical and Bacterial Quality of the Water at the Different Stations in the Bay at Low and High Tides (T = top and B = bottom samples)

	D.O. % Sat.		B.O.D. p.p.m.		B. Coli MPN/Ml.		Chlorides ppm		Fe ppm	
Sta.	LT	HT	LT	HT	LT	HT	LT	HT	LT	HT
20 T	74	100	2.1	2.9	10.5	7.3	14,500	15,800	.2	.1
20 B	62	84	1.8	2.0	5.0	3.7	14,800	16,000	.3	.3
19 T	74	90	2.0	1.9	16	11.3	14,800	16,000	.4	.1
19 B	59	80	1.0	1.7	20	12.1	14,800	15,900	.4	.3
18 T	70	98	2.2	2.5	47	28.5	14,000	15,600	.4	.2
18 B	63	86	1.7	2.1	67	42.4	14,400	15,400	.5	.3
17 T	76	133	2.2	3.5	63	34.9	14,000	15,300	.3	.2
17 B	65	113	2.0	3.2	19	14.5	13,800	15,900	.4	.4
16 T	69	108	1.8	2.7	96	51.6	13,500	15,100	.4	.3
16 B	63	111	2.1	2.4	48	25.8	13,700	15,900	.4	.3
15 T	67	92	1.8	2.3	78	43.0	13,600	15.500	.5	.3
15 B	61	82	1.8	1.8	90	49.0	14,100	15,500	.5	.3
14 T	65	85	1.5	3.2	68	38.6	13,700	15,700	.3	.2
14 B	57	77	1.6	1.8	54	30.5	14,500	15,500	.3	.3
13 T	71	95	1.7	1.8	6.8	6.9	14,600	15,300	.2	.1
13 B	69	93	1.7	1.8	7.0	8.7	14,700	15,900	.2	.2
12 T	60	78	1.3	2.0	186	100	13,500	15,700	.3	.1
12 B	54	70	1.6	1.3	12.3	11.2	14,300	16,000	.3	.2
11 T	64	76	1.7	2.3	166	100	13,400	15,200	.4	.4
11 B	59	70	1.3	2.0	31	25.3	13,700	15,500	.3	.4
10 T	66	87	2.2	1.8	196	105	13,500	15,400	.8	.3
10 B	63	71	1.5	1.6	206	109	13,700	15,200	.5	.3
9 T	79	119	2.6	3.4	65	38.8	12,900	15,000	.4	.2
9 B	74	106	2.3	2.4	29.4	19.7	13,500	15,400	.4	.3
8 T	82	83	3.0	4.6	9.6	8.0	13,600	15,200	.3	.3
8 B	86	123	3.7	4.4	16.7	20.0	13,800	15,000	.3	.3
7 T	68	73	1.9	1.6	165	117	12,700	15,100	.6	.4
7 B	68	94	2.8	3.3	138	77.1	13,300	15,300	.5	.5
6 T	61	67	1.6	2.1	156	117	12,100	14,700	.6	.7
6 B	53	65	1.2	2.0	93	80	13,500	15,000	.7	.8
5 T	62	73	1.6	2.4	11.6	13	13,400	15,200	.3	.2
5 B	52	66	1.3	2.4	23	15	13,700	15,200	.2	.4

It is apparent, however, that D.O. saturation in the bay is not critically low, even with the lowest dissolved oxygen saturation recorded.

The average B.O.D. values at different stations were found to be low and satisfactory. The differences between the different stations were small. A maximum value of 4.6 ppm was obtained at station 8 in the top high tide samples. The minimum of 1.0 ppm occurred at station 19 in the samples taken at low tide from the bottom. All other B.O.D. values obtained were between those figures. Generally, the samples taken with the incoming tide had higher B.O.D. values than those from outgoing tide and samples taken from the surface had higher B.O.D. values than those at the bottom.

The coliform bacteria were generally lower in samples taken during incoming tide than those taken during outgoing tide. Coliform organisms were higher in the top samples at some stations and in the bottom samples at other stations. The lowest numbers occurred at station 13, 19 and 20, whereas the highest numbers occurred at stations 6, 7, 10, 11 and 12.

As may be expected, the chloride content of both surface and bottom samples were higher at all stations at incoming tide than at outgoing tide. In general, the samples from the bottom had a higher chloride content than the surface samples.

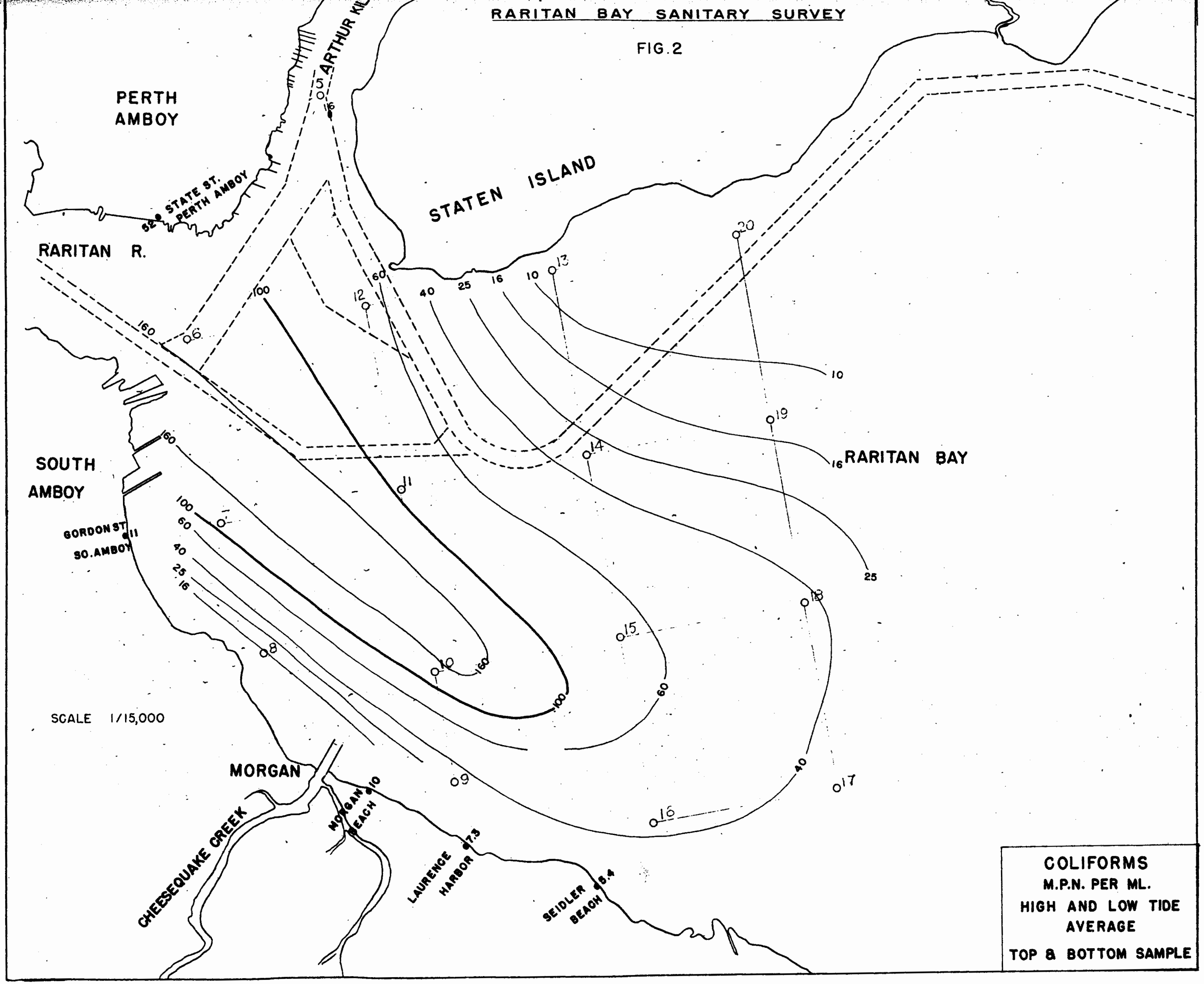
The average iron content varied from a minimum of 0.1 ppm to a maximum of 0.8 ppm. The lower values generally occurred at the stations located nearer to the outer section of the bay.

The most significant measure of the pollution is perhaps the numbers of coliform organisms present in the water. As indicated above, the dissolved oxygen deficiency is not a major problem in the bay and the B.O.D. values are generally low. Chlorides are valuable in determining the pattern of tidal flow, but as a pollution indicator the chloride concentration in brackish water is of little direct value. Similarly, the iron content in the bay water is useful in establishing the pattern of tidal flow. The average coliform density at different stations is graphically illustrated in Fig. 2. These are the average of 8 sampling periods, including high and low tide values as well as top and bottom samples at each station. Considering the variability of coliform counts, it is desirable to present the picture of the existing conditions on the basis of overall averages of 16 samples made in duplicate rather than to attempt to show differences between high and low tides and top and bottom samples.

The greatest density of coliform organisms (160 per ml.) extends as a narrow tongue from the mouth of the river to station 10. The coliform density drops off on either side of this tongue with a steeper gradient towards the New Jersey shore of the bay and at a more gentle gradient toward Staten Island. At the perimeter nearest to the New Jersey shore, coliform numbers reached a minimum of 16 per ml. Hence, it is apparent that the greatest coliform numbers are found in the inner section of the bay, extending toward the N. J. shore and that the numbers decrease outward into the bay.

RARITAN BAY SANITARY SURVEY

FIG. 2



b. Discussion

The status of pollution of the section of the Raritan Bay surveyed in 1950 is presented in a further condensed form in Table 2. The average composite picture is shown by the results obtained at all the stations during high and low tides and from top and bottom. The B.O.D. values are low. A maximum average value for all stations of 2.6 p.p.m. was obtained in the samples taken from the top at high tide and a minimum average of 1.9 p.p.m. at low tide from the bottom samples. The overall average of all samples from top and bottoms at low and high tides from all the stations shows a B.O.D. of 2.2 p.p.m. It might be concluded that the organic pollution coming from the river is diluted by salt water and stabilized to such an extent that it does not present any problem on the oxygen balance of the bay. This is confirmed by the average dissolved oxygen saturation values. The minimum average value of 64 percent saturation was obtained in bottom samples at low tides and a maximum average of 92 percent in top samples at high tide with an overall average for all stations at high and low tides from tops and bottoms of 78 percent. The bay is, therefore, in a satisfactory condition in respect to dissolved oxygen. It is of interest to note that there was appreciably more dissolved oxygen in the top samples than in the bottom samples for respective stages of the tide, and considerably more in the high tide samples than in the low tide samples both for corresponding top and bottom samples. The higher values for high tides are to be attributed to the oxygen contributed by the incoming salt water from the outer

TABLE 2

Condensed Results of Raritan Bay and Arthur Kill Samples

Bay Samples 6 - 20 Inclusive	BOD ppm	D.O. Sat. %	Coliforms MPN/Ml.	Chlorides ppm	Fe ppm
High Tide Tops	2.6	92	19	15,300	.3
High Tide Bottoms	2.2	88	15	15,600	.4
High Tide Top and Bottoms	2.4	90	17	15,450	.3
Low Tide Tops	2.0	70	88	13,600	.4
Low Tide Bottoms	1.9	64	56	14,000	.4
Low Tide Top and Bottoms	1.9	67	72	13,800	.4
Low Tide and High Tide Bottoms and Tops	2.2	78	44	14,600	.4

TABLE 3

Arthur Kill Sample No. 5

High Tide Tops	2.4	73	14.5	15,200	.2
High Tide Bottoms	2.4	66	6.9	15,200	.4
High Tide Tops and Bottoms	2.4	70	10.7	15,200	.3
Low Tide Tops	3.6	62	11.6	13,400	.3
Low Tide Bottoms	3.4	52	23.0	13,700	.2
Low Tide Top and Bottoms	3.5	57	17.3	13,500	.3
Low Tide and High Tide Tops and Bottoms	2.9	63	14.0	14,300	.3

Bay containing a relatively higher dissolved oxygen content. The higher dissolved oxygen content of top samples in comparison with the bottom samples is the result of surface reaeration.

The D.O. saturation values increased from the mouth of the river outward into the bay and from the shore areas toward the middle of the bay.

The coliform densities are highest near the mouth of the river and in the middle of the bay, decreasing on either side toward the shores. The position of the area of maximum density in the bay shifts with tidal conditions. There is a tendency for the bacterial pollution coming from the river to approach the New Jersey shore.

The average numbers of coliform organisms from all stations at all stages of the tide and from top and bottom is 44 per ml. A maximum average number of 88 per ml. occurred in samples collected at low tide from the top as compared with 19 coliforms per ml. obtained from in the top samples at high tide. The bottom samples had similarly higher values at low tide than at high tide. The factors contributing to this phenomenon are: (1) the flow of pollution along the surface of the bay and (2) the stage of the tide affecting the degree of pollution or dilution within this section of the bay.

The chloride values substantiate these observations. The chloride content was lower in the low tide samples both at the top and bottom than the corresponding samples taken at high tide, indicating lower dilution with salt water.

The iron content of all samples taken from the different stations in the bay did not show significant variations with the tide nor between the top and bottom samples. The overall average of all stations at all tides from tops and bottoms was 0.4 ppm.

The results from the sampling station at the end of Arthur Kill near the Raritan Bay are summarized in Table 3. It is evident that the average B.O.D. values of all samples taken from the top and bottom and at high and low tides was slightly higher than the corresponding values of all the stations in the bay. The following tabulation illustrates the relative B.O.D. values in Arthur Kill as compared with all the stations in the Bay and stations 6 and 12 in the Bay nearest to the sampling station in Arthur Kill:

	BOD ppm
All stations in bay, high and low, top and bottom	2.2
Station 6 high and low, top and bottom	1.7
Station 12 high and low, top and bottom	1.5
Arthur Kill high and low, top and bottom	2.9

The Arthur Kill samples show appreciably higher B.O.D. values both in top and bottom samples at low than at high tide.

The dissolved oxygen saturation in the Arthur Kill was also slightly less than the Bay as a whole, but is not worse than the stations in the Bay nearest to the Kill as illustrated in the following figures:

	D.O. Saturation %
All stations in bay, high and low, top and bottom	78
Station 6, high and low, top and bottom	61
Station 12, high and low, top and bottom	65
Arthur Kill, high and low, top and bottom	63

Similar to the Bay the Arthur Kill had appreciably lower D.O. at low tide, both in top and bottom, than at high tide.

Comparison of coliform numbers in the Kill and the Bay samples shows:

	Coliform MPN/Ml.
All stations in Bay, high and low, top and bottoms	44
Station 6 in Bay, high and low, top and bottom	111
Station 12, in Bay, high and low, top and bottom	77
Arthur Kill, high and low, top and bottom	14

The Arthur Kill shows definitely lower coliform pollution than the adjacent stations in the bay, as well as the section of the bay as a whole.

The average salinity in the Arthur Kill was approximately the same as that found in the Bay as a whole; similar to the Bay, the salinities were definitely lower at low tides than at high tides both in the top and bottom samples.

A comparison of the pollution of the river at Victory Bridge just before the river empties into the bay and the station nearest to the mouth of the river (Station 6) is given below:

	BOD ppm	D.O. Sat. %	Coliforms MPN per ml	Chlorides PPM
River at Victory Bridge	2.9	51.5	440	12,600
Bay Station 6, nearest mouth of the River	1.7	61	99	14,850

The distance between these two stations is about 1.5 miles. Within this distance considerable reduction of B.O.D. and coliform organisms took place and an increase in D.O. saturation values was found. The changes correspond to the increased dilution of the river water by bay water as indicated by the increase in chloride content of the bay samples.

c. Conclusions

The chemical and bacteriological survey made of the bay water during the low river flow period in July and August 1950, permits the following conclusions to be drawn:

1. The organic pollution in the bay, as measured by B.O.D., is low and does not present a problem in regard to the oxygen balance. The dilution and self-purification in the river as well as in the bay are responsible for the reduction of the pollutional load originating from municipalities and industries.

2. The dissolved oxygen condition in the bay can be considered non-critical. The average minimum for the entire bay was 64 percent saturation, while the minimum for any sampling station at any given time during the survey was 50 percent. Stabilization of the pollution load is brought about without seriously affecting the dissolved oxygen content of the water, because of oxygen supplied by the incoming salt water and surface reaeration.

3. The dissolved oxygen concentration in the bay is sufficiently high to prevent the fish population to be affected by a deficiency in oxygen.

4. The bacterial pollution, as measured by the density of coliform organisms, is relatively high. It is highest near the mouth of the river and extends as a tongue into the bay bending toward the New Jersey shore and decreasing from the center toward both edges of tongue.

5. As indicated by the D.O. content and coliform density conditions in the bay were poorest during low tide and best during high tide.

6. A higher density of coliform organisms occurs near the surface of the bay, indicating that water with relatively lower density coming from the river flows near the surface. This effect is more pronounced at low tide.

7. Higher D.O. saturation values are present near the surface of the bay than near the bottom, pointing toward the greater influence of surface reaeration as compared with oxidation of pollutional material.

8. The organic pollution of Arthur Kill, as measured by B.O.D. values, is higher than in the bay as a whole and at the mouth of the Raritan River. The coliform density in the Kill is decidedly lower than in the waters in the bay as a whole, and at the mouth of the Raritan. The dissolved oxygen content of the waters in the Kill is materially lower than the bay as a whole and about the same as in the water at the mouth of the Raritan River.

9. It appears that the pollution in the Arthur Kill is primarily organic in nature, possibly mainly of industrial origin, since the number of coliform organisms is comparatively low and the B.O.D. relatively high.

10. The pollution in the Arthur Kill has a deleterious effect on the waters of the bay.

11. The organic pollution concentration at the lower end of the Arthur Kill is greater than at the mouth of the Raritan River.

III. RARITAN RIVER SURVEY

The location of sampling stations in the Raritan River is given in Fig. 3.

a. Tidal Section.

The average results of the survey of the tidal section of the Raritan River are given in Table 4 and Figs. 4,5, 6 and 7. The averages include all samples taken from surface and bottom of the river at high and low tides.

The dissolved oxygen content at Johnson Dock and College Bridge was extremely low. Above the confluence of the Washington Canal and the Raritan River the D.O. in the river water showed a recovery. The recovery continued downstream. At the Victory Bridge (at the last sampling station before the river empties into the bay) the D.O. content had increased to 4.0 ppm or 51.5 percent saturation. The South River at Old Bridge was devoid of D.O. At Washington Canal station, above the junction with the Raritan River, the D.O. had increased only to 0.8 ppm.

The average B.O.D. at Johnson Dock was 23.3 ppm and at College Bridge 20.4 ppm. Four miles below the College Bridge above the confluence of the Washington Canal and river, the B.O.D. in the Raritan River decreased to 4.6 ppm. Three and a half miles below this point, at the Raritan Arsenal, the B.O.D. decreased to 3.2 ppm and at Victory Bridge it was reduced to 2.9 ppm. In the South River at Old Bridge the B.O.D. was 91 ppm, which decreased at the mouth of Washington Canal to 4.5 ppm.

The coliform organisms were extremely high at Johnson Dock and College Bridge stations (57,000 and 62,000 per milliliter

TABLE 4

RARITAN RIVER SURVEY 1950

Average Chemical and Bacteriological Results (Top and Bottom and High and Low Tide) In the Tidal Section

Most Probable Number

Location	Date	No. Sample	Temp. °C.	D.O. ppm	% Sat.	pH	Acidity ppm	Alk. ppm	Turb. ppm	Chloride ppm	Total Fe ppm	BOD ppm	Coliform MPN /L
Non-Tidal Section													
R2 North Branch	8/14-8/18	5	22	7.4	83	8.0	0	67	7.6	7.4	.14	1.1	13
R3 Finderne	8/14-8/18	5	23	6.8	79	7.9	0	72	9.0	8.0	.14	1.6	460
R4 Millstone	8/14-8/18	5	23	9.8	113	7.7	2.0	25	22	8.0	.47	4.0	15
R5 Green Brook	8/14-8/18	5	22	2.2	25	7.1	22	120	10	66	.60	4.2	105
R6 Bound Brook	8/14-8/18	5	24	2.3	27	7.1	15	52	61	74	1.58	42.0	190
R7 Landing Bridge	8/14-8/18	5	23	2.7	31	7.2	13	70	43	70	1.12	35.0	3,500
Tidal Section													
A Johnson Dock	8/2-8/15	3	25	0.3	3	6.8	17	70	53	1,000	1.23	23.3	57,000
B College Bridge	8/2-8/15	3	25	0.1	1.0	6.9	15	79	55	1,760	1.34	20.4	62,000
1 Washington Canal	7/24-8/15	8	24	0.8	8.0	7.2	15	86	34	6,700	1.2	4.5	5,610
2 Raritan Above Washington Canal	7/24-8/15	8	24	0.7	9.0	7.2	12	84	30	6,700	1.1	4.6	7,900
3 Raritan Arsenal	7/24-8/15	8	24	2.7	41	7.3	16	85	31.5	10,100	1.1	3.2	1,300
4 Victory Bridge	7/24-8/15	8	23	4.0	51.5	7.5	16	101	25	12,600	1.1	2.9	440
R11 South River at Old Bridge	8/16-8/18	3	24	0	0	7.2	18	92	235	277	1.9	91.0	28,000

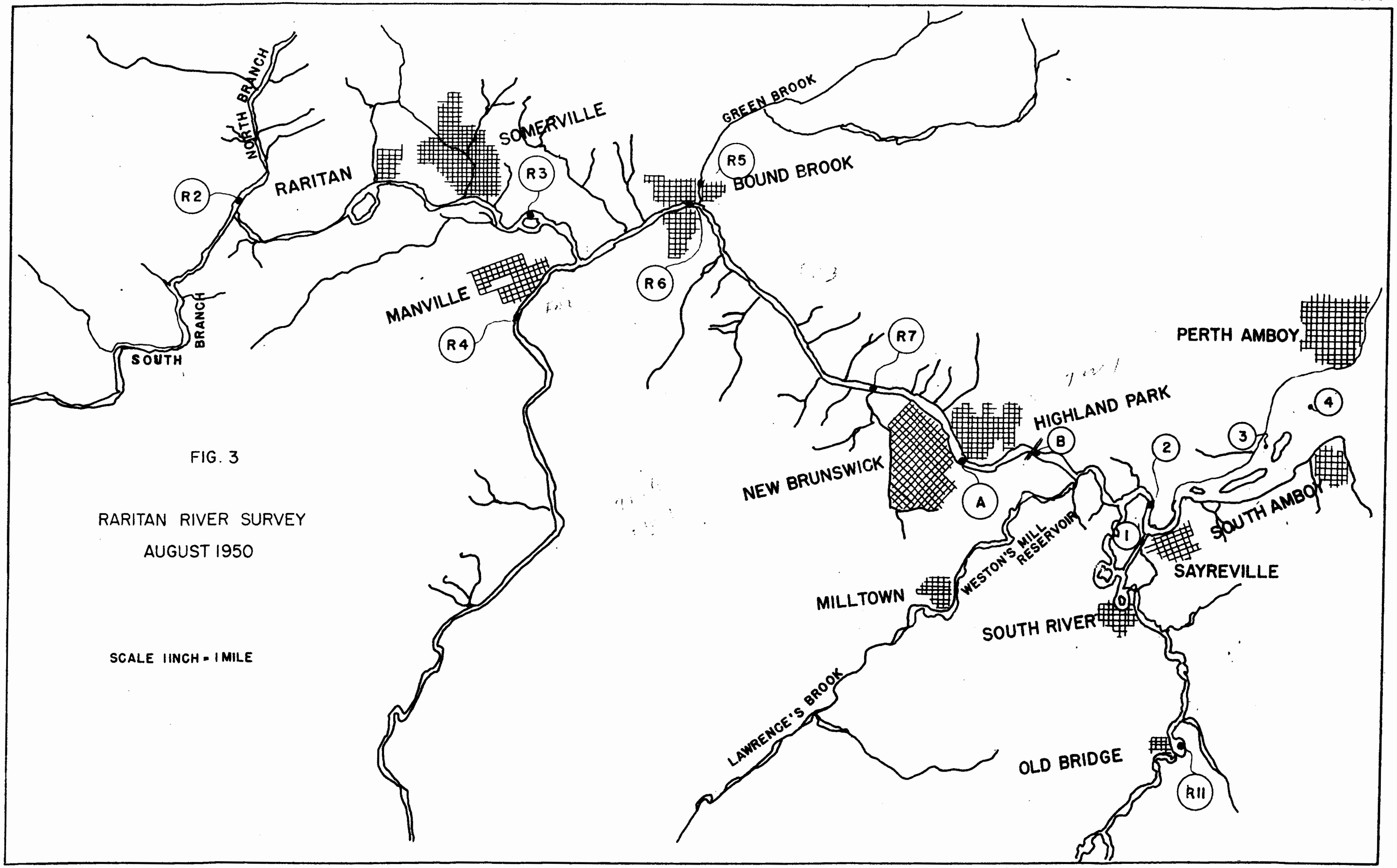
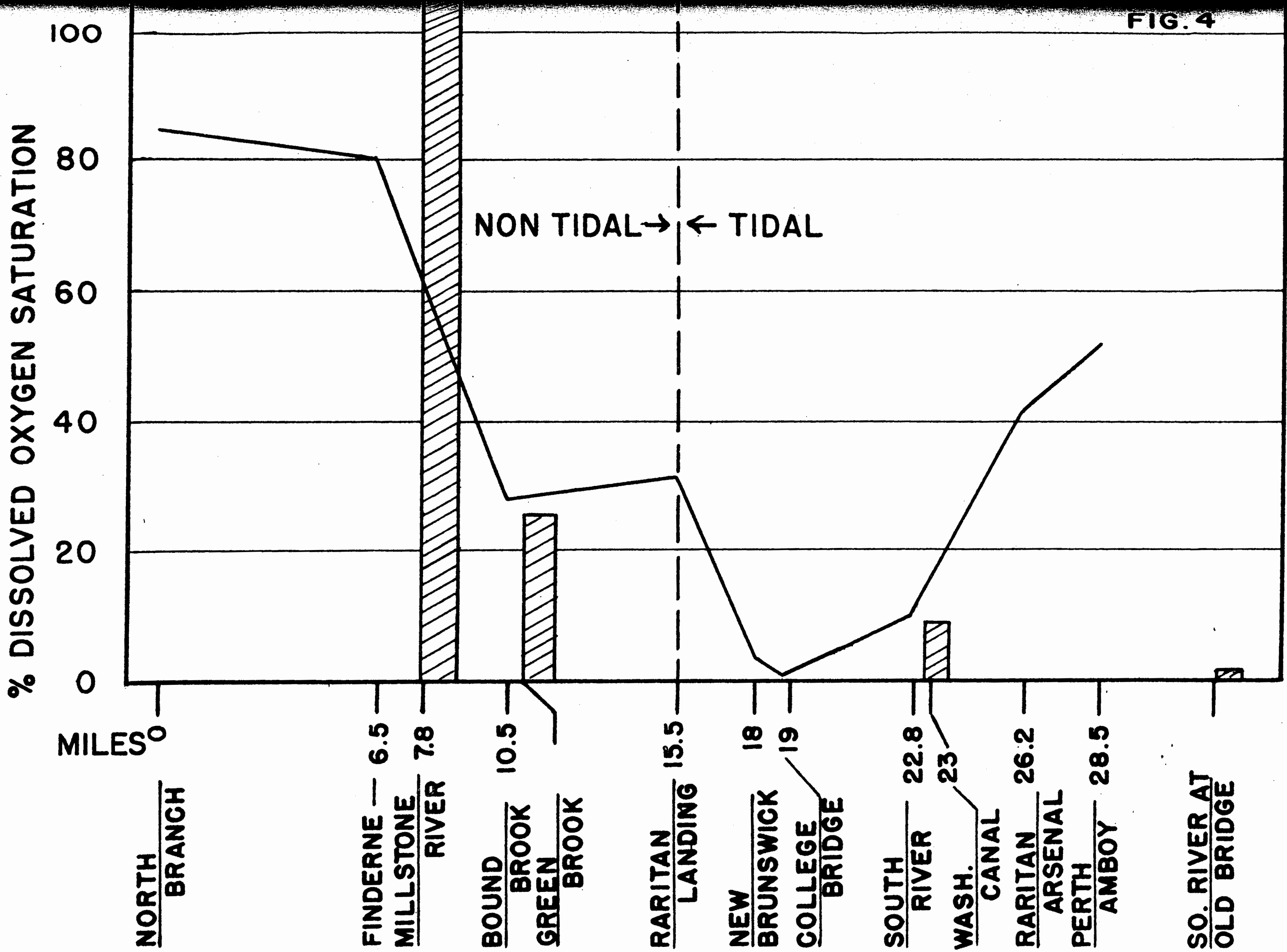

NORTH BRANCH
RARITAN
R2
SOMERVILLE
R3
GREEN BROOK
R5
BOUND BROOK
R6
MANVILLE
R4
SOUTH
BRANCH
R7
PERTH AMBOY
HIGHLAND PARK
B
NEW BRUNSWICK
A
2
3
4
1
SOUTH AMBOY
SAYREVILLE
WESTON'S MILL RESERVOIR
MILLTOWN
0
SOUTH RIVER
LAWRENCE'S BROOK
OLD BRIDGE
R11
FIG. 3
RARITAN RIVER SURVEY
AUGUST 1950
SCALE 1 INCH = 1 MILE

FIG. 4



100
80
60
40
20
0
% DISSOLVED OXYGEN SATURATION
NON TIDAL→
← TIDAL
MILES
0
6.5
7.8
10.5
15.5
18
19
22.8
23
26.2
28.5
NORTH BRANCH
FINDERNE
MILLSTONE RIVER
BOUND BROOK
GREEN BROOK
RARITAN LANDING
NEW BRUNSWICK
COLLEGE BRIDGE
SOUTH RIVER
WASH. CANAL
RARITAN ARSENAL
PERTH AMBOY
SO. RIVER AT OLD BRIDGE

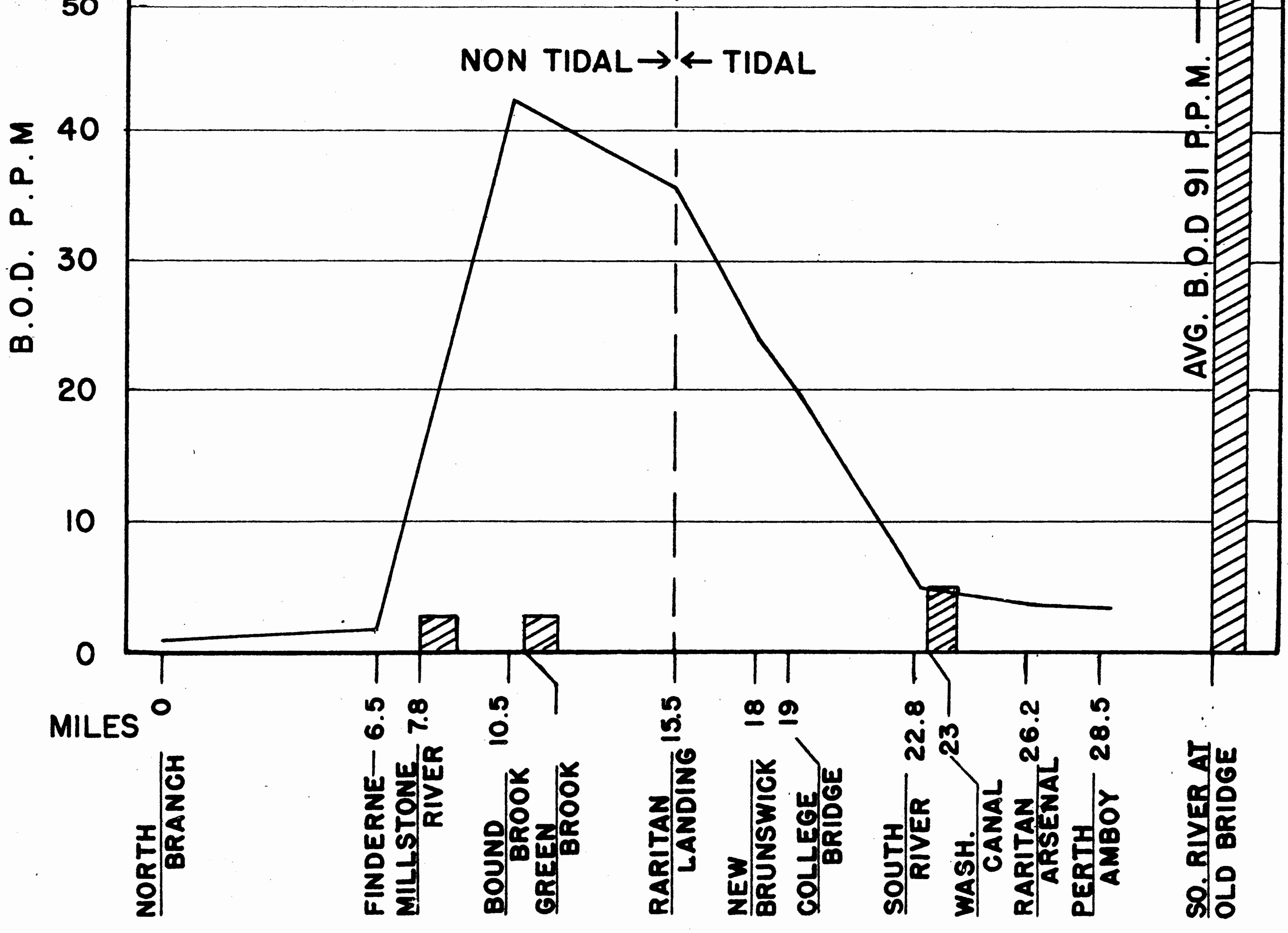
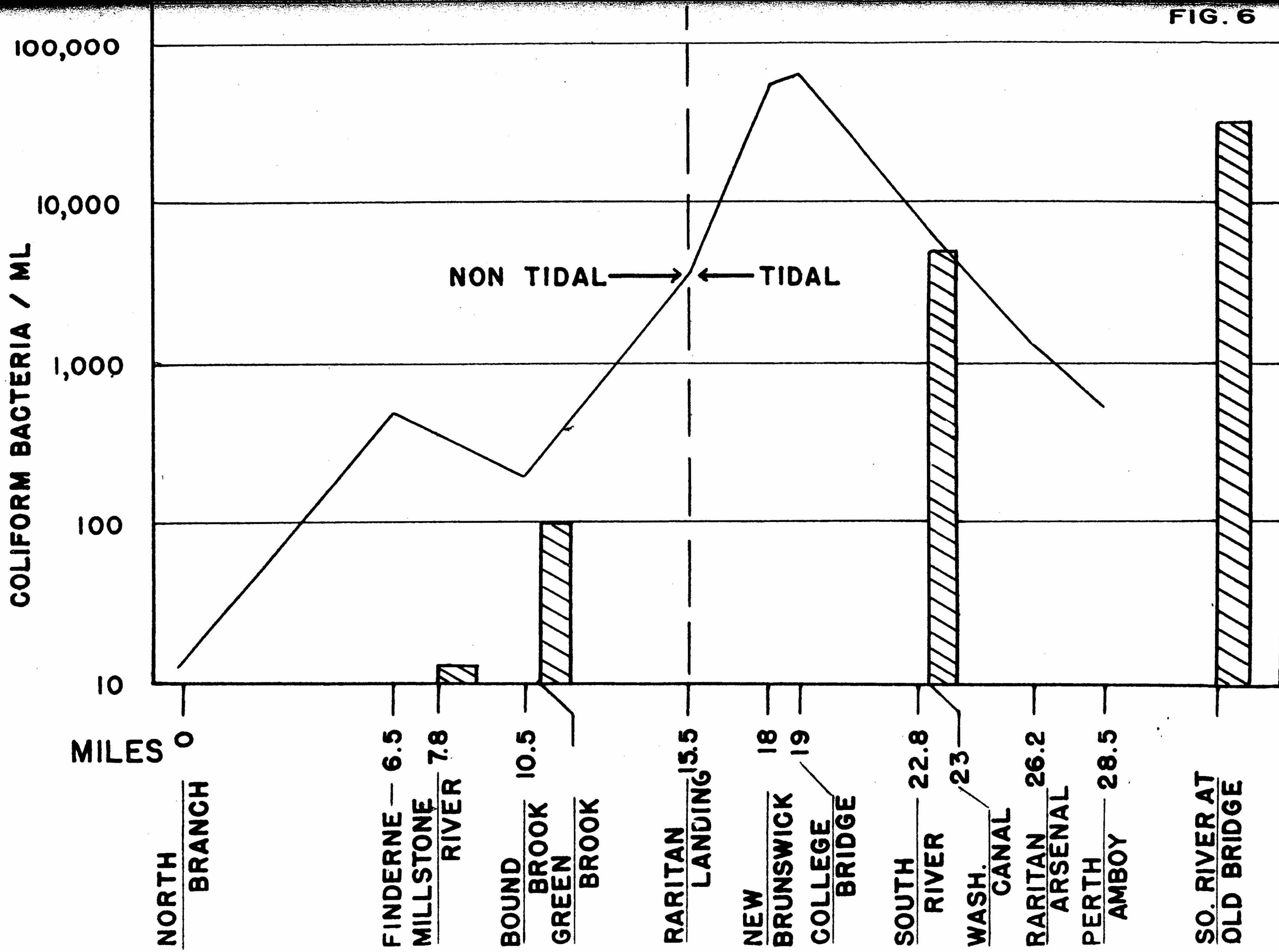

B.O.D. P.P.M
50
40
30
20
10
0
NON TIDAL → ← TIDAL
AVG. B.O.D 91 P.P.M.
MILES
0
6.5
7.8
10.5
15.5
18
19
22.8
23
26.2
28.5
NORTH BRANCH
FINDERNE
MILLSTONE RIVER
BOUND BROOK
GREEN BROOK
RARITAN LANDING
NEW BRUNSWICK
COLLEGE BRIDGE
SOUTH RIVER
WASH. CANAL
RARITAN ARSENAL
PERTH AMBOY
SO. RIVER AT OLD BRIDGE

FIG. 5

FIG. 6



COLIFORM BACTERIA / ML
100,000
10,000
1,000
100
10
NON TIDAL
TIDAL
MILES
0
6.5
7.8
10.5
15.5
18
19
22.8
23
26.2
28.5
NORTH BRANCH
FINDERNE
MILLSTONE RIVER
BOUND BROOK
GREEN BROOK
RARITAN LANDING
NEW BRUNSWICK
COLLEGE BRIDGE
SOUTH RIVER
WASH. CANAL
RARITAN ARSENAL
PERTH AMBOY
SO. RIVER AT OLD BRIDGE

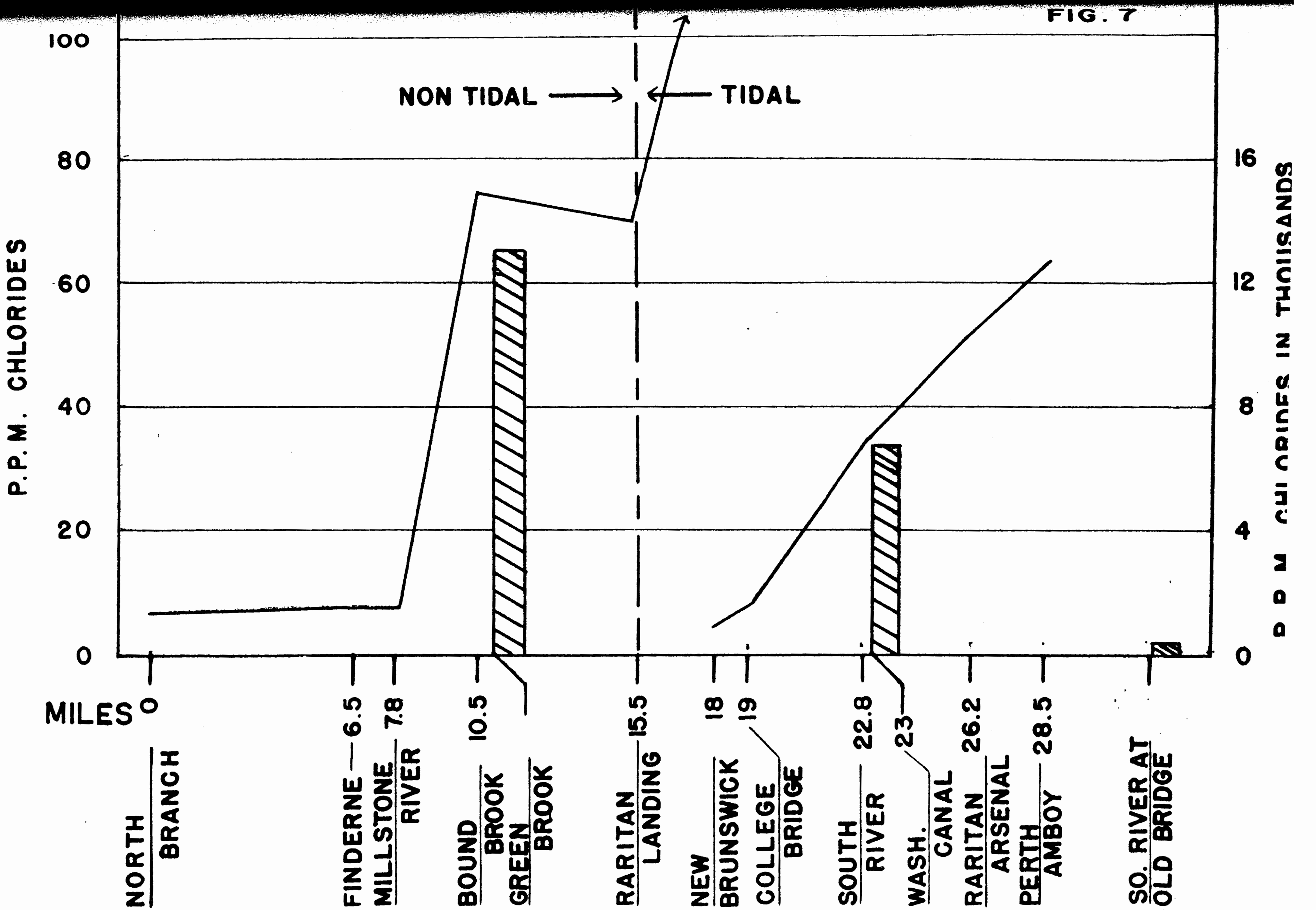
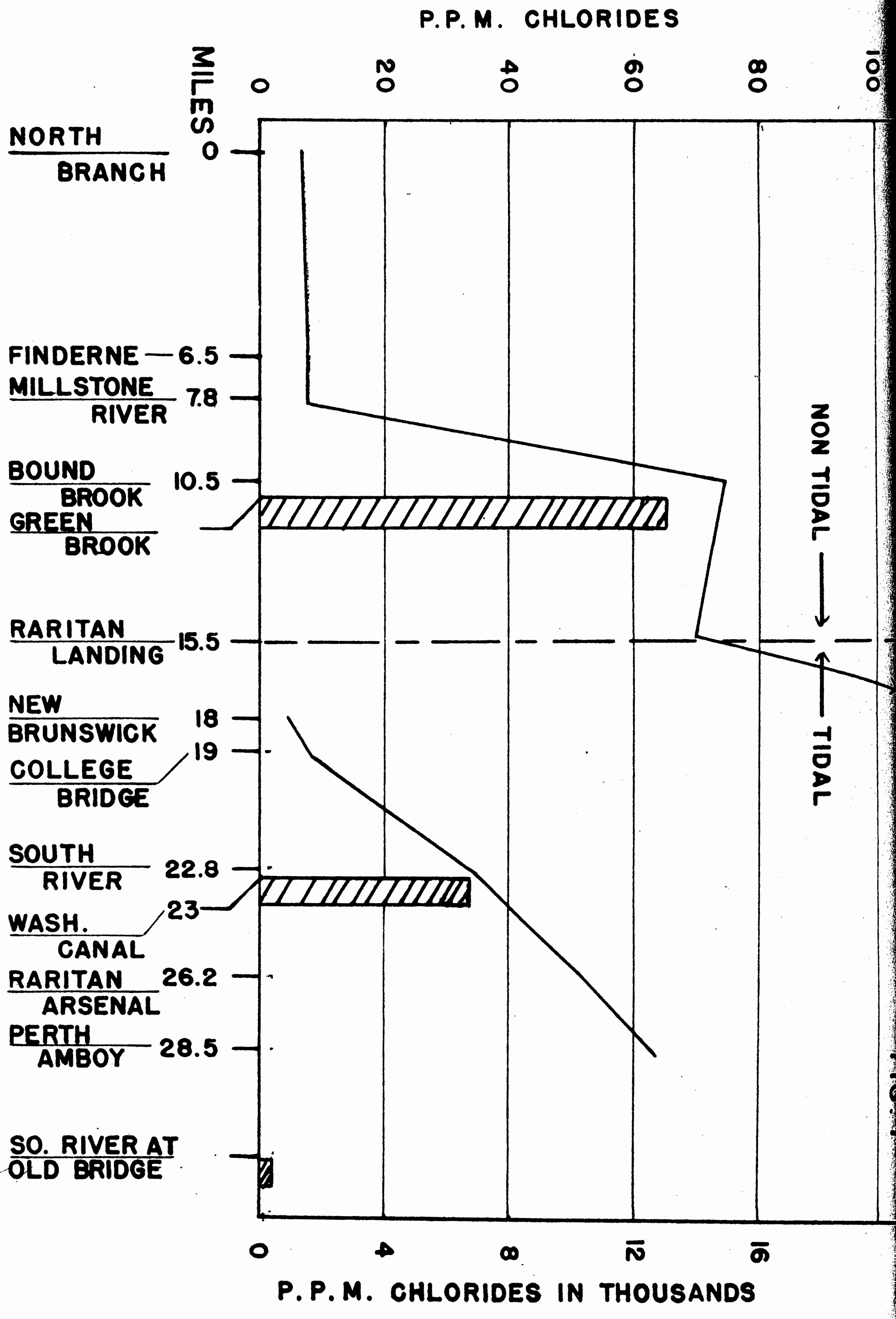


FIG. 7
NON TIDAL
TIDAL
P.P.M. CHLORIDES
P.P.M. CHLORIDES IN THOUSANDS
100
80
60
40
20
0
16
12
8
4
0
MILES
0
6.5
7.8
10.5
15.5
18
19
22.8
23
26.2
28.5
NORTH BRANCH
FINDERNE
MILLSTONE RIVER
BOUND BROOK
GREEN BROOK
RARITAN LANDING
NEW BRUNSWICK
COLLEGE BRIDGE
SOUTH RIVER
WASH. CANAL
RARITAN ARSENAL
PERTH AMBOY
SO. RIVER AT OLD BRIDGE



P.P.M. CHLORIDES
0
20
40
60
80
100
MILES
NORTH BRANCH 0
FINDERNE 6.5
MILLSTONE RIVER 7.8
BOUND BROOK 10.5
GREEN BROOK
RARITAN LANDING 15.5
NEW BRUNSWICK 18
COLLEGE BRIDGE 19
SOUTH RIVER 22.8
WASH. CANAL 23
RARITAN ARSENAL 26.2
PERTH AMBOY 28.5
SO. RIVER AT OLD BRIDGE
NON TIDAL
TIDAL
0
4
8
12
16
P.P.M. CHLORIDES IN THOUSANDS

respectively). There was a regular decrease below the College Bridge down to Victory Bridge, where the number of coliforms was 440 per ml. The coliforms in the South River samples at Old Bridge were very high (28,000 per ml.). At the mouth of Washington Canal, above the confluence with the Raritan River, there were 5610 coliforms per ml.

The decreases in B.O.D. and coliforms organisms and the increase in D.O. from New Brunswick to the Victory Bridge, and in the South River from Old Bridge to just above the confluence with the Raritan River, are affected by the dilution with the tidal water. This is indicated by the chloride content of the water, which increases regularly downstream in both the main river and in the tributary. It is not possible to determine with certainty whether in addition to the dilution, natural self-purification factors are exerted, because the dilution is not brought about by unpolluted salt water. However, since the time required for passage of the water from New Brunswick to Victory Bridge is reckoned in terms of days, it is reasonable to assume that there is self-purification in addition to dilution. This is especially the case in regard to coliform organisms, which are destroyed rapidly in salt water.

The picture in regard to the iron content at successive sampling points downstream is again affected by the dilution, but in this case there is no appreciable decrease in the iron concentration in the downstream stations, indicating that additional amounts of iron are discharged into the river between New Brunswick and the Victory Bridge.

The average pH value of the water at New Brunswick was 6.8 and increased to a value of 7.5 at the Victory Bridge sampling station. Similarly, the alkalinity increased from 70 to 101 ppm, while the acidity was low and remained fairly constant. The turbidity decreased from 53 ppm at New Brunswick to 25 ppm at the Victory Bridge.

b. Non-Tidal Section.

The non-tidal section of the Raritan River includes the stations from North Branch to Landing Bridge and the tributaries, Millstone and Greenbrook. The results of the non-tidal section of the river are presented together with the tidal section, in order to show the overall picture for the entire length of the river (Table 4 and Figures 4,5, 6 and 7).

The river at North Branch had a high D.O. value of 7.4 ppm or 83 percent saturation which dropped slightly at Finderne. The Millstone River was supersaturated (113 percent), while the Greenbrook showed only 25 percent of oxygen saturation. The D.O. in the main stream dropped from 79 percent saturation at Finderne to 27 percent at Bound Brook and increased to 31 percent at Landing Bridge.

The B.O.D. increased from 1.1 ppm at North Branch to 1.6 ppm at Finderne and to 42 ppm at Bound Brook. At Landing Bridge it had decreased to 35 ppm. The B.O.D. values of the Millstone and Greenbrook were 4.0 ppm. The coliform organisms increased appreciably between North Branch and Finderne (from 13 to 400 per ml.) with a decrease to 190 per ml. at Bound Brook and a sharp increase to 3,500 ppm at Landing Bridge. The Millstone river water had a relatively low coliform count of 15 per ml., but in Greenbrook the coliforms organisms were higher (105 per ml.).

c. Load on the Stream.

The B.O.D. load on the stream from the effluents of present municipal sewage and industrial effluents is given in Tables 5 & 6. The flows and the B.O.D. values are on the basis of the average values obtained from 5 hourly samples taken from 10 A.M. to 2 P.M. They, therefore, represent the maximum flows and maximum B.O.D. loads discharged from municipal plants and those industries operation during the day only, and should be considered as the maximum pollution conditions. In the case of New Brunswick, Plainfield Joint Meeting and Raritan Borough, exceptions were made by taking the average flows and the B.O.D. values of samples collected over longer periods. These exceptions were made because long term results would presumably be nearer the actual conditions that the results obtained on the basis of five hour composites taken during one day. The flows, B.O.D. contribution, and population equivalents of the municipal and industrial effluents are summarized in Table 7. The total flow recorded was 103 mgd with 37.5 mgd contributed by municipal plants and 65.5 mgd by industries. The total B. O. D. discharged to the river was 127,245 lbs. with 43,485 lbs. or 34 percent contributed by municipal plants and 83,760 lbs., or 66 percent contributed by industries. The total population

TABLE 5

Contributed to the River B. O. D. by Effluents of Municipal Plants

	Volume* mgd	BOD ppm	BOD Lbs./ Day	B.O.D. Population Equivalent +
Bound Brook	0.6	310	1,550	9,300
Diehl Mfg. Co.	0.05	6	2	12
Highland Park	.98	123	1,025	6,150
Manville	0.8	13	85	510
Johns Manville Res. Center	0.12	3	3	18
Metuchen	0.65	100	540	3,240
Middlesex Borough	1.1	395	3,595	21,570
New Brunswick #	9.4	260	20,300	121,800
North Brunswick	0.5	115	478	2,868
Perth Amboy	6.9	85	4,845	29,070
Plainfield #	8.3	25	1,725	10,350
Raritan Borough #	.5	205	860	5,160
Raritan Twp. Piscataway Sect.	1.25	126	1,260	7,560
Raritan Twp. Clara Barton	.27	135	300	1,800
Rutgers	.13	10	10	60
Sayreville	.63	42	220	1,320
Sayreville Twp. Melrose Sect.	.01	46	5	30
Somerville	1.7	155	2,170	13,020
So. Amboy	.65	205	1,250	7,500
So. Bound Brook	0.2	176	290	1,740
So. River	1.4	127	1,475	8,850
Woodbridge Twp.	0.54	112	505	3,030
	37.47		43,483	262,910

\# On the basis of records.

\+ Factor of 0.167 used for converting B.O.D. values to population equivalents.

* The flows and B.O.D.'s are on the basis of 1950 survey.

TABLE 6

B.O.D. Contributed to the River by Industrial Plants

	Flow* mgd	BOD* ppm	B.O.D. #/day	Population Equivalent
Amer. Agr. Prod.	0.2	6.7	11	66
Anheuser Busch	0.8	1,600	10,560	63,360
Bakelite	0.1	6,236	7,330	43,980
Benzole Prod.	0.07	1,082	632	3,796
Calco	20.5	209	35,530	213,180
Carey Mfg. Co.	0.5	531	2,208	13,248
Dreyfus	0.036	33	10	60
Dupont Photo Prod.	1.47	230	2,805	16,830
Dupont F & F Plant	1.32	52	570	3,420
Ford	0.017	156	22	132
Hercules Powder Co.	5.7	67	2,180	19,080
Heyden Chem. Wks.	0.25	2,265	4,710	28,260
Johns Manville	4.6	65	2,500	15,000
National Lead	28.0	5.6	1,305	7,830
Ruberoid	--	--	--	--
Schweitzer	2.08	721	12,385	74,310
Sherwin Williams	--	--	--	--
	65.5		83,760	502,550

* On the basis of 5 hour period of sampling from 10 A.M. to 2 P.M., 1950 survey.

TABLE 7

Flow and B.O.D. Contributed by Municipal and Industrial Plants

	Municipal	Industrial	Total
Flow, mgd.	37.47	65.5	103
Flow, % of Total	36.5	63.5	
# B.O.D. per Day	43,485	83,760	127,245
# B.O.D., % of Total	34	66	
Population Equivalent	262,910	502,550	765,460

equivalent discharged into the river was 765,460 lbs. of which 262,910 lbs. was contributed by municipal plants and 502,550 lbs. by industries. Considerable amounts of industrial wastes are treated in municipal plants and no attempt has been made to assess the quantity or characteristics of such wastes.

A check was made of the lbs. B.O.D. discharged into the river by municipalities and industries above Bound Brook and of the actual amount found by analysis of the river at Bound Brook (Table 8). The total discharged into the river amounted to 42,165 lbs. of B.O.D. to which must be added the B.O.D. of the Millstone River 1530 lbs. and the B.O.D. of North and South Branch of 580 giving a grand total of 44,275 lbs. Analysis of the river water at Bound Brook showed that the water contained 39,700 lbs. of B.O.D. or about 10 percent less than calculated from the discharged effluents. A part of this discrepancy may be attributed to the fact that the B.O.D. discharged to the river was calculated on the basis of peak flows and loads during the day. Another part of the discrepancy might be attributed to sedimentation and oxidation of the materials discharged into this stretch of the river. A similar comparison below Bound Brook cannot be made because of the tidal effect below New Brunswick.

A comparison has been made of the population equivalent in the River at Bound Brook from 1927 to 1950. (Table 9). In 1927 sewage and industrial wastes produced in this stretch of the river were not treated with two exceptions. At that

TABLE 8

B.O.D. of Effluents Discharged and B.O.D. Found in the River
(Pounds Per Day)

		Discharged
Manville Plant		85
Somerville Plant		2,170
Raritan Plant		1,877
Calco		35,530
Johns Manville Res. Center		3
Johns Manville		2,500
Total		42,165
Millstone River		1,530
North and South Branch (109 cfs @ 1.0 ppm)		580
	Grand Total	44,275
Found in the River at Bound Brook		39,700

TABLE 9

Population Equivalent in the Raritan Above Bound Brook over

The Period 1927 - 28 - 1950

Year	Pop. Eq.
1927 - 28	88,200
1937 - 38	107,000
1940 - 41	171,200
1950	238,000

time the population equivalent in the river was 88,200. In 1937-38 most of the municipal sewage and some of the industrial wastes were being treated but despite this the population equivalent increased to 107,000. In 1940 a number of the larger industries had built treatment facilities and yet the population equivalent increased to 171,200. In 1950 the population equivalent in the river at Bound Brook had increased further to 238,000.

d. Discussion

Pollution of the tidal and non-tidal section of the Raritan River and the tributaries.

The various criteria of pollution such as B.O.D., D.O., and coliform organisms clearly indicate an increasing progressive pollution of the river from North Branch down to New Brunswick and with increasing dilution by salt water an apparent gradual improvement in the conditions down to the Victory Bridge. There is a pronounced increase in pollution between Manville and Bound Brook. The Millstone River does not contribute to the pollution in this stretch, but on the contrary alleviates the conditions by furnishing additional volume of relatively unpolluted water. The pollution derived from the municipalities and industries is responsible for the deterioration of the river in this stretch. Within a four mile distance between Manville and Bound Brook the D.O. dropped from 80 percent saturation to 27 percent; the B.O.D. increased from 1.6 ppm to 42 ppm. There was a significant decrease of coliform organisms from 460 to 190 per ml. The latter is to be attributed to the effect of industrial wastes on the survival of the bacteria. The high coliform count at Manville is due to the influence of domestic sewage.

Greenbrook emptying into the river below Bound Brook had a low D.O. content (25% saturation) despite a relatively low B.O.D. of 4.2 ppm. The coliform count in the Greenbrook was 105 per ml. The condition of this tributary is dominated by the discharge of large volumes of completely treated municipal effluent into a relatively small volume of water. The sluggish flow does not afford much atmospheric reaeration to replenish the oxygen utilized by the residual organic materials in the effluent from the treatment plant.

Between Bound Brook and Landing Bridge further deterioration of the river is arrested despite the additional sources of pollution entering from industrial and municipal origins. This is reflected by a stationary D.O., B.O.D. and coliform levels between these two points. Self-purification processes within this 5 mile stretch is sufficient to counter balance the influence of additional pollution.

At New Brunswick, the river reaches its lowest state of degradation. The dissolved oxygen content had all but disappeared and the coliform count had reached a fantastically high value for a river. The B.O.D., however, was lower than at Landing Bridge. The following influences are at work at this point:

1. Cumulative pollution from upstream.
2. Pollution derived from New Brunswick.

3. Effect of sludge deposits.

4. Effect of dilution with salt water.

Without the latter factor the B.O.D. would probably be higher. The disappearance of dissolved oxygen with decreasing B.O.D. values can be attributed to the oxygen demand exerted by the bottom deposits. The presence of such deposits was prominently in evidence by floating black sludge solids and bubbling of gas covering a large area below Johnson's Dock.

That the pollution below New Brunswick is not confined to a small local area but exerts its influence for a considerable distance is evidenced by the comparison of the results obtained at Johnson's Dock and College Bridge. Within a distance of over a mile the pollutional condition remains practically unchanged despite the considerable additional dilution (increased chlorides). In fact the improvement of the river at a point above Washington Canal four miles further downstream was reflected only by a decrease in B.O.D. from 20.4 ppm to 4.6 ppm, and a decrease of coliform organisms from 62,000 to 7,900 per ml., while the dissolved oxygen was still at a very low level (9 percent saturation). The decrease in B.O.D. was the result of dilution and oxidation of the pollutional material. Reaeration and dilution supplied somewhat more oxygen than was utilized, thereby increasing the D.O. level slightly.

The dissolved oxygen level increased gradually downstream until at Victory Bridge it reached a 51.5 percent saturation value, the B.O.D. dropped to 2.9 ppm and the coliform organisms to 440 per ml.

The South River discharging into the lower Raritan River was highly polluted at Old Bridge with zero dissolved oxygen, 91 ppm B.O.D. and 28,000 coliforms per ml. Before the South River discharges into the Raritan, the D.O. had increased to 8 percent of saturation, the B.O.D. decreased to 4.5 ppm and the coliform organisms to 5600 per ml. The decrease in B.O.D. and coliform organisms was primarily the result of dilution.

The flow measurements and analyses of municipal and industrial effluents contributing to the pollution of the river have revealed that the river received a total pollution load equivalent 765,000 population (on B.O.D. basis) of which 66 percent is of industrial origin. It is possible to balance the pollution load discharged into the river with that found by actual analysis of the river for the section above Bound Brook. A similar comparison was not made for the section below because of the complications arising from the tidal dilution. Effluents from municipal and industrial plants above Bound Brook discharged daily 42,165 lbs.of B.O.D. to which must be added the B.O.D. contributed by the Millstone River and Raritan River itself above the sources of pollution. A total of 44,275 lbs. of B.O.D. per day came from these various sources. At Bound Brook 39,700 lbs. of B.O.D. per day was actually found. The agreement is satisfactory considering the various possible sources of error in the measurements of flow and in sampling of the river and of the effluents. In addition, a part of the difference might be attributed to the self-purification taking place in the river during the passage time from the points of discharge to Bound Brook.

A comparison of the pollution load in the river over a period of 20 years on the basis of previous surveys shows that at Bound Brook the population equivalent (on the basis of B.O.D.) has steadily increased from 88,000 in 1927 - 28 to 238,000 in 1950. During this period a number of municipal and industrial plants were constructed but their effects have been counterbalanced by the increase in population and industrial activity. Most of municipal treatment plants are either overloaded or otherwise inadequate to check the further deterioration of the river.

e. Conclusions

On the basis of the 1950 river survey, measurements, analyses, and calculations, the following conclusions can be drawn:

1. The Raritan River pollution increases progressively and reaches a maximum at New Brunswick. Below this point there is a gradual improvement, with increasing dilution with salt water.

2. A B.O.D. of 42 ppm and a D.O. saturation of 27 percent was obtained at Bound Brook.

3. At Bound Brook the B.O.D. load of the river checked closely with the B.O.D contributed by municipal and industrial effluents.

4. There is a pollutional population equivalent at Bound Brook of 238,000. The organic pollution of the river expressed in population equivalent increased nearly four fold

during the past 20 years despite all the pollution abatement efforts and projects.

5. The total population equivalent of the treated and untrested municipal and industrial waste effluents discharging into the river was 765,500 of which, 66 percent was industrial.

6. There were evidences of self-purification forces at work in the stream as illustrated by the leveling of the indices of pollution between Bound Brook and Landing Bridge. However, the natural self-purification powers are overtaxed.

7. The river just below New Brunswick manifests the effects of cumulative pollution from upstream as well as from New Brunswick. Despite the decrease in B.O.D., resulting from dilution with salt water, the D.O. content was negligible and coliform organisms reached a maximum level. There were evidences of extensive sludge deposits taxing the oxygen resources and creating offensive conditions.

8. Below New Brunswick dilution and the self-purification power of the river are responsible for improvement of the conditions.

9. Of the major tributaries, the Millstone showed the least pollution, Greenbrook was fairly heavily polluted and South River at Old Bridge showed a degree of pollution higher than the Raritan River at its worst.

IV. MUNICIPAL AND INDUSTRIAL EFFLUENTS SURVEY

A survey was made of all municipal and industrial waste treatment plants and untreated effluents discharged by industries not connected with municipal sewers to determine:

a. The existing conditions.

b. Performance of the treatment plants.

c. The relative contributions each municipality and industry may make to the proposed trunk sewer.

The survey of each municipal and industrial treatment plant or effluents discharged by industries not connected with municipal sewerage systems was made over a period of five consecutive hours of a given day. Samples were taken every hour (from 10 A.M. to 2 P.M.) and analysed separately to determine variations and fluctuations. The flows were measured during the sampling periods, and where available, the daily flows recorded for the preceeding week. In some instances flows and analyses were available over extended periods of time. A total of 660 samples were taken from municipal plants and 600 from industries. Approximately 1430 individual analyses were made on municipal sewage and 1400 on industrial wastes.

a. Existing Conditions.

All results obtained have been averaged and summarized in Tables I and J in the appendix.

The suspended solids and B. O. D. loads contributed at present by the raw sewage from municipalities and the untreated wastes from industries were calculated on the basis of the average concentration of these constituents obtained during this survey and on the basis of the prevailing flows at the time the samples were taken. These results do not represent the average conditions, because there are hourly and daily variations in flow and the concentration of these constituents. The results represent more or less the maximum contributions from municipalities and industries. The results of these calculations are presented in Tables 10 and 11. They are further summarized below:

	Flow mgd	Susp. Solids lbs/day	B.O.D. lbs/day	Pop. Eq.
Municipalities	37.77	86,950	167,800	1,006,800
Industries	64.37	67,845	83,450	500,730
Total	102.14	154,795	251,250	1,507,530

The total flow was 102 mgd, of which 37 percent was derived from municipalities. The municipalities contributed 56 percent of the suspended solids and 66 percent of the B.O.D. On a B.O.D. basis the total population equivalent was 1,507,530 of which 66 percent was contributed by the municipalities. It should be kept in mind that considerable quantities of industrial wastes are discharged into municipal sewers.

The average pH values of the raw sewage and of the effluents from municipalities are generally either slightly acid or slightly alkaline. They show a tendency to decrease as a result of treatment. In no case, however, was there a serious problem from the standpoint of pH values. There are wide

TABLE 10

Flows, Suspended Solids, B.O.D. of Raw Sewage from Municipalities (1)

	Flow mgd	Suspended Solids lbs./day	B.O.D. lbs./day
Bound Brook	0.6	1,600	2,850
Diehl Mfg. Co.	0.05	25	55
Highland Park	0.8	1,825	2,220
Johns Manville Res. Center	0.12	25	40
Manville	0.8	1,450	1,980
Metuchen	.65	1,830	2,160
Middlesex	1.06	1,390	7,270
New Brunswick	10.5	38,000	88,500
North Brunswick	0.5	650	1,200
Perth Amboy	6.9	13,300	11,300
Plainfield	8.3	13,400	30,800
Raritan	1.1	2,900	4,730
Raritan Twp. Clara Barton	0.27	520	440
Raritan Twp. Piscataway	1.2	175	2,300
Rutgers University	.13	110	120
Sayreville	0.6	1,200	1,340
Sayreville Melrose Sect.	0.01	25	20
Somerville	1.3	2,120	3,270
So. Amboy	0.74	1,740	2,540
So. Bound Brook	0.2	205	575
So. River	1.4	3,020	2,960
Woodbridge Twp.	0.54	1,400	1,200
Total	37.77	86,950	167,800

(1) on the basis of the averages obtained during the survey

TABLE 11

Flows, Suspended Solids, B.O.D. of Industrial Wastes (1)

	Flow mgd	Suspended Solids lbs/day	B.O.D. lbs/day
Amer. Agr. and Chem. Co.	0.2	555	20
Anheuser Busch	0.8	1,300	10,680
Bakelite	0.08	800	4,150
Benzol Prod.	0.07	15	630
Calco	20.5	30,500	40,600
Dreyfus	.04	180	810
Dupont Photo Prod.	1.47	145	2,820
Dupont F. & F. Plant	1.32	190	570
Ford	.017	25	20
Hercules	5.04	3,190	4,200
Heyden	0.3	375	4,450
Johns Manville	2.3	12,100	595
National Lead	30.0	8,500	1,400
Ruberoid	0.1	455	5
Schweitzer	2.08	9,500	12,500
Sherwin Williams	.05	15	5
	64.37	67,845	83,455

(1) On the basis of averages obtained during the survey.

fluctuations in the pH values of the wastes from a few municipalities due to the presence of large volumes of industrial wastes.

The alkalinity of the sewages varied from a minimum of 74 ppm to a maximum of 300 ppm. With one exception, treatment resulted in a decrease in the alkalinity.

No generalizations can be made in regard to the dissolved oxygen content of the raw sewages from the municipalities. In 11 out of 22 municipal plants studied the raw sewage contained no D.O., whereas only 2 plants had no D.O. in the effluents.

Three industrial plants had effluents with pH values as low as 1.8 to 2.9. Other industries with acid wastes with pH values lower than 4.0 were neutralized before discharge. There were two industries discharging wastes with pH values above 9.0.

The results of oxygen consumed and of special analyses of certain industrial wastes are given in Tables K and L in appendix.

b. <u>Performance of Plants</u>

Sewage treatment plants are designed to produce certain degrees of purification. The performance and efficiency of the plants can be evaluated on the basis of certain criteria. Two of these criteria are suspended solids and B.O.D. An appraisal of the efficiency of the municipal sewage treatment plants is indicated in Table 12. The actual efficiencies are compared with expected values for the various types of treatment plants. For the plain sedimentation type of plants

TABLE 12

Efficiency of Suspended Solids and B.O.D. Removal of Municipal Plants

	Type of Plant	Suspended Solids Removal Actual %	Suspended Solids Removal Expected %	B.O.D. Removal Actual %	B.O.D. Removal Expected %
Bound Brook	Chem. Treatment	80	80	46	65
Diehl Mfg. Co.	Trickling Filter	95	85	95	85
Highland Park	Pl.Sedimentation	72	60	63	35
Johns Manville Res. Center	Pl.Sedimentation	65	60	62	35
Manville	Trickling Filter	92	85	96	85
Metuchen	Trickling Filter	78	85	78	85
Middlesex Boro	Chem. Treatment	53	80	52	65
New Brunswick	Chem. Treatment	50	80	14	65
North Brunswick	Trickling Filter	34	85	60	85
Perth Amboy	Chem. Treatment	77	80	56	65
Plainfield	Trickling Filter	89	85	95	85
Raritan Boro	Chem. Treatment	84	80	60	65
Raritan Twp. Pisc.	Pl.Sedimentation	55	60	44	35
Raritan Twp.Clara Barton	Pl.Sedimentation	52	60	44	35
Rutgers	Trickling Filter	88	85	91	85
Sayreville	Chem. Treatment	82	80	85	65
Sayreville Twp. Melrose Sect.	Pl.Sedimentation	70	60	82	35
Somerville	Chem. Treatment	91	80	49	65
So. Amboy	Pl.Sedimentation	59	60	50	35
So. Bound Brook	Pl.Sedimentation	54	60	49	35
So. River	Chem. Treatment	58	80	50	65
Woodbridge Twp.	Pl.Sedimentation	71	60	58	35

suspended solids removal of 60 percent and B.O.D. removal of 35 percent is taken as the norm. A suspended solids removal of 80 percent and B.O.D. removal of 65 percent is taken as the norm for chemical treatment type of plants. Trickling filter plants are expected to remove 85 percent of B.O.D. and suspended solids. The number of plants of various categories meeting or failing to meet the expected suspended solids and B.O.D. efficiencies are tabulated in Table 13. Our of 8 plain sedimentation plants, 3 failed to produce the expected suspended solids removals, and all produced percentages B.O.D. reduction equal to or higher than the expected value. Of the 8 chemical treatment type of plants 4 produced suspended solids efficiencies lower than expected value and 7 failed in respect to B.O.D. Only one plant produced the performance expected of this type of treatment. There are 6 trickling filter type of plants, two of which failed in respect to suspended solids efficiency, and 2 in respect to B.O.D. efficiency. Of the 22 plants of all types only 10 plants were producing B.O.D. and suspended solids efficiencies in accordance with expectations for their respective types of treatment.

A similar analyses of industrial waste treatment, plants, given in Table 14 is not very revealing because: (1) Five of the 16 plants studied do not have treatment facilities, (2) The rest but one have either neutralization alone or conjunction with lagoons, (3) In some instances neutralization

TABLE 13

Number of Municipal Plants Meeting or Failing to Meet the B.O.D. and Suspended Solids Efficiency Values Expected for their Respective Types of Treatment

	Pl. Sed.	Chem. Tr.	Trickling Filter	Total
Total Number of Plants	8	8	6	22
Number failing to meet susp. solids efficiency	3	4	2	9
Number failing to meet B.O.D efficiency	0	7	2	9
Number failing either in S.S. or B.O.D. efficiency or both	3	7	2	12
Number meeting both S.S. and B.O.D. efficiency	5	1	4	10

TABLE 14

PERFORMANCE OF INDUSTRIAL TREATMENT PLANTS

	Type of Treatment	Susp. Solids Removal %	B.O.D. Removal %
American Agr. Chem. Co.	Sedimentation	34	36
Anheuser Busch	None	--	--
Bakelite	Composting and Neutralization	--	--
Benzol Products	Neutralization and Lagoons	--	--
Calco	Neutralization and Lagoons	95	12
Dreyfus	Complete Treatment	79	99
Dupont Photo Prod.	None	--	--
Dupont F & F	None	--	--
Ford	None	--	--
Hercules	Neutralization	415	33
Heyden	Lagoons	790	27
Johns Manville	Lagoons	95	90
National Lead	Neutralization	--	--
Ruberoid	Plain Sedimentation	90	220
Schweitzer	None	--	--
Sherwin Williams	Lagoons	--	--

results in an increase in suspended solids due to precipitation. Moreover, because of the diversity of industrial wastes it is difficult to establish a normal expected efficiency of suspended and B.O.D. removals.

The performance of municipal and industrial waste treatment plants can be approached from the standpoint of the quality of the effluents produced as compared with the present day requirements for the individual plants. The present day requirements are based, among others, on B.O.D. and coliform numbers. The actual and the required B.O.D. and coliform values for each individual municipal plant are given in Table 15 and summarized in Table 16.

Thirteen of the 22 plants studied failed to meet the B.O.D. requirements; 15 failed in respect to coliform requirements; 16 failed either in respect to B.O.D. or coliform requirements or both and only 6 were discharging effluents in conformity with the present day requirements.

A similar tabulation of the quality of effluents from industrial plants is given in Table 17. The numbers of plants failing or conforming to their respective present day B.O.D. and coliform requirements are summarized in Table 18. Out of 16 plants, 9 failed to meet the B.O.D. requirements; 5 the coliform requirements and 11 were in violation of either or both of these requirements. Only 5 plants were discharging effluents according to the B.O.D. and coliform requirements. In addition, there are requirements related to turbidity, color,

TABLE 15

Quality of Effluents from Municipal Plants

		Suspended Sol.	B.O.D.		Coliform	
	Zone	Actual ppm	Actual ppm	Requirement ppm	Actual MPN/ml.	Max. Allowable
Bound Brook	I	82	310	70	10,000	< 1 (1)
Diehl Mfg. Co.	Potable	3	6	70	0	< 1 (2)
Highland Park	II	76	124	100	8,400	< 1 (1)
Johns Manville Res. Center	Potable	9	3	70	0	< 1 (2)
Manville	Potable	20	13	70	1,350	< 1 (2)
Metuchen	I	74	100	70	10,000	< 1 (1)
Middlesex Boro	I	73	395	70	280	< 1 (1)
New Brunswick	II	218	872	100	6	< 1 (1)
North Brunswick	Special	103	116	40	1.5	< 1 (1)
Perth Amboy	ISC(4)	54	85	--	7.0	< 1 (3)
Plainfield	Special	22	25	30	57	< 1 (1)
Raritan Boro.	Potable	49	206	30	--	< 1 (2)
Raritan Twp. Piscataway	II	78	126	100	4,600	< 1 (1)
Raritan Twp. Clara Barton	II	112	135	100	46	< 1 (1)
Rutgers	II	12	10	70	0.4	< 1 (1)
Sayreville	II	44	42	100	0	< 1 (1)
Sayreville Twp. Melrose Sect.	ISC(4)	80	46	--	0	< 1 (3)
Somerville	Potable	18	155	30	1.5	< 1 (2)
So. Amboy	ISC(4)	117	205	--	0.8	< 1 (3)
So. Bound Brook	I	56	176	70	1,600	< 1 (1)
So. River	II	112	127	100	17	< 1 (1)
Woodbridge Twp.	II	93	112	100	85	< 1 (1)

(1) Should be absent in five 1 ml. portions in 80% of the time in Zone I and II.

(2) Should be absent in five 1 ml. portions in 90% of the time in potable zone.

(3) Should be absent in five 1 ml. portions in 50% of the time in ISC zone.

(4) ISC - Interstate Sanitation Commission (requirement 60% removal of suspended solids)

TABLE 16

Number of Municipal Plants Failing or Conforming to the Present Day B.O.D. and Coliform Requirements

Failing to meet B.O.D. requirements	13
Failing to meet coliform requirements	15
Failing to meet either for B.O.D. and coliform requirements	16
Meeting both requirements	6

TABLE 17

Quality of Effluents from Industrial Plants

	Zone	Susp. Sol.* Actual ppm	B.O.D. Actual ppm	B.O.D. Requirement ppm	Coliform Actual MPN/L	Coliform Req.
Amer. Agr. and Chem. Co.	ISC	217	6.7	--	28	< 1 (3)
Anheuser Busch	II	195	1,600	100	960,000	< 1 (1)
Bakelite	I	1,200	6,236	70	0	< 1 (1)
Benzol Products	II	2.8	1,082	100	0	< 1 (1)
Calco	I	9.6	209	70	0	< 1 (1)
Dreyfus	S	114	33	35	0	< 1 (1)
Dupont Photo Products	II	12	230	100	.7	< 1 (1)
Dupont F. & F.	II	17.6	52	100	2.4	< 1 (1)
Ford	S	192	156	30	0	< 1 (1)
Hercules	II	395	67	100	0	< 1 (1)
Heyden	II	1,340	2,265	100	4,400	< 1 (1)
Johns Manville	P	32	59	25	1,100	< 1 (2)
National Lead	II	34	5.6	100	0	< 1 (1)
Ruberoid	I	55	15	70	0	< 1 (1)
Schweitzer	II	548	721	100	0	< 1 (1)
Sherwin Williams	I	38	9	70	0	< 1 (1)

S = special, P = potable, ISC = Interstate Sanitation Commission.

* requirement, no noticeable turbidity 1,000 feet below outfall.

(1) should be absent in five 1 ml. portions in 80% of the time in zones I and II.

(2) should be absent in five 1 ml. portions in 90% of the time in potable zone.

(3) should be absent in five 1 ml. portions in 50% of the time in ISC zone.

TABLE 18

Number of Industrial Plants Failing or Conforming To the Present Day B.O.D. and Coliform Requirements

Failing to Meet B.O.D. Requirements	9
Failing to Meet Coliform Requirements	5
Failing to Meet Either for B.O.D. and Coliform Requirements	11
Meeting both Requirements	5

oil, sleek, taste and odor producing substances, poisons, acidity, and alkalinity, which must be taken into consideration in regard to industrial effluents. When any or all of these criteria are used possibly two industrial effluents (small volumes) would meet all requirements.

c. Relative Contributions of Each Municipality and Industry

The contributions of B.O.D. and suspended solids from each municipality and industry to the proposed trunk sewer are estimated on the basis of the best figures available. The following procedures have been followed in obtaining the data:

1. Flow, suspended solids and B.O.D. figures were used on the basis of records available over as long a period as possible for as many plants as possible.

2. Where such records were not available the results obtained from the present survey were used.

3. In the case of some industries it was assumed that as much cooling water as possible would be removed before discharging into the trunk sewer.

The results are given in Tables 19 and 20. The adjusted flow from municipalities is 5 mgd lower than the values on the basis of flows obtained during the survey. The pounds of suspended solids contributed by municipalities on the basis of two methods of calculations are in close agreement, but the B.O.D. contributed on the basis of adjusted values are less than those obtained on the basis of the survey. This

TABLE 19

Flow, B.O.D., and Suspended Solids Contribution from Municipalities

	Flow mgd	S.S. ppm	BOD ppm	S.S. lbs/day	B.O.D. lbs/day	B.O.D. Pop. Equiv.
Bound Brook	0.6	332	571	1,600	2,850	17,100
Diehl Mfg. Co.	0.045	66	132	24	48	288
Highland Park	0.8	274	332	1,825	2,220	13,300
Johns Manville Res. Cent.	.11	26	42	24	40	240
Manville	0.7	225	265	1,315	1,545	9,270
Metuchen	0.65	300	350	1,620	1,890	11,340
Middlesex Boro	0.6	190	620	950	3,100	18,600
New Brunswick	9.4	502	570	39,156	44,460	266,760
North Brunswick	0.5	156	288	650	1,200	7,200
Perth Amboy	6.9	205	215	11,790	12,360	74,160
Plainfield	5.4	275	275	12,375	12,375	74,250
Raritan	0.5	225	290	945	1,220	7,320
Raritan Twp. Pisc.	1.2	174	227	1,740	2,270	13,600
Raritan Twp. Clara Barton	0.3	232	195	580	485	2,910
Rutgers	0.13	102	112	110	120	720
Sayreville	0.6	290	300	1,450	1,500	9,000
Sayreville Twp. Melrose Sect.	.012	264	257	26	26	155
Somerville	1.3	196	302	2,120	3,270	19,600
So. Amboy	0.65	320	370	1,730	2,000	12,000
So. Bound Brook	0.2	122	346	203	576	3,460
So. River	1.1	269	255	2,470	2,340	14,000
Woodbridge Twp.	0.8	260	220	1,735	1,465	8,790
	32.49			84,500	97,360	584,000

TABLE 20

Flow, B.O.D., and Suspended Solids Contribution from Industries

	Flow mgd	S.S. ppm	BOD ppm	S.S. lbs/day	B.O.D. lbs/day	BOD Pop. Equiv.
Amer. Agr. and Chem. Co.	0.2	333	11	530	17	100
Anheuser Busch	0.8	195	1,600	1,300	10,670	64,020
Bakelite	0.1	1,200	6,236	1,000	5,360	32,160
Benzol Products	0.07	3	1,082	17	650	3,900
Calco	20.5	179	238	30,430	40,460	242,760
Dreyfus	.03	547	2,400	165	730	4,380
Dupont Photo Prod.	2.1	12	230	210	4,025	24,150
Dupont F. & F. Plant	1.32	17.5	52	190	570	3,420
Ford	.017	192	156	27	22	132
Hercules	7.0	76	100	7,885	5,840	35,040
Heyden	0.3	151	1,300	325	3,250	19,500
Johns Manville	4.6	1,560	89	59,600	3,400	20,400
National Lead	4.5	34	5.6	1,275	210	1,260
Ruberoid	0.1	546	4.6	540	8	50
Schweitzer	2.08	548	721	9,425	12,385	74,310
Sherwin Williams	.05	38	200	20	85	510
	43.77			112,940	87,980	527,900
						234
						761,000

difference is mainly due to basic figures used in connection with some municipalities. It is believed that the adjusted values represent more nearly the present average daily contribution.

The flow contribution from industries is about 20 mgd less than the value obtained on the basis of the survey, because of assumed elimination of cooling waters. The suspended solids contribution on the basis of adjusted values is about 45,000 lbs. per day higher while the B.O.D. contribution on the basis of the two calculations are nearly alike.

Using the adjusted values as better approximation of the expected contribution to the trunk sewer, the flow, pounds suspended solids and B.O.D., and population equivalents are as follows:

	Total	Municipalities %	Industries %
Flow, mgd	76	42.5	57.5
Suspended Solids, lbs.	197,450	43.0	57.0
B.O.D., lbs.	185,340	52.5	47.5
Pop. Equivalents	1,111,900	52.5	47.5

d. Discussion

The excessive pollution of the Raritan River has been established on the basis of the survey. The responsibility for the condition of the river may be summed up by stating that the treatment facilities have not kept pace with the increase in population and industrial expansion. Only 6 out of 22 municipal plants are meeting the present day requirements for effluent quality. The flow from the plants meeting present requirements represents a very small fraction of the aggregate flow from municipalities (1.6 mgd out of a total of 37.8 mgd). Even some of these plants will not be able to meet the future, more stringent, requirements. The 16 municipal plants which are now unable to meet the present requirements will need expansion and extension of their facilities. Fifteen of these plants are unable to meet the coliform requirements. The available records show that in many of these plants the residual chlorine in the effluent was low or absent. There are a number of plants which are maintaining satisfactory chlorine residuals, but do not produce an effluent within the requirements. The causes in such instances are either inadequate pretreatment or inadequate chlorine contact tank facilities. These plants will require increased facilities to enable them to meet just the coliform requirements. However, even if all the municipal plants were able to meet the coliform requirements, some 13 plants would still be confronted with the problem of reducing the B.O.D. in their effluents to the required level. The causes for the failure of these plants to meet the B.O.D. requirements are revealed from their performance records. There are eight municipal plants with plain sedimentation alone. All of these are operating at efficiencies equal to or higher than normally expected from such type of treatment and yet 5 of these plants are unable to meet the present B.O.D. requirements. It follows that these five plants cannot comply with the requirements by additional sedimentation facilities and that a higher degree of treatment such as trickling filters will be required. The three plain sedimentation type of plants which at present are able to meet the present B.O.D. requirements may have to go to a higher degree of treatment when in the future the requirements are raised.

Of the 8 chemical treatment type of plants seven are not giving the expected efficiency of B.O.D. removal from this type of treatment and 6 of them are not able to meet present day requirements of the B.O.D. in the effluent. Addition of more chemicals or construction of additional chemical treatment units for these plants will not prove adequate. Therefore, these plants also will have to go to a higher degree of treatment such as trickling filters. The other two plants, which at present are able to meet the requirements, may in the future have to go to secondary treatment when the requirements are raised. Of the 6 existing trickling filter type of plants, two are operating below the efficiency expected from this type of treatment and these two are also not meeting the present day requirements. They must increase the capacity of their present day filters to be able to comply.

In summarizing the present day situation and future requirements of the municipal plants it is apparent that 5 plain sedimentation plants, 6 chemical treatment type of plants and 2 trickling filter plants need major construction to increase their treatment facilities for B.O.D. removal in addition to improving their efficiency of disinfection by either (a) increasing the chlorine dosage, (b) installing increased chlorinator capacity and/or (c) making provision for better mixing and contact. To state the problem differently, the type of treatment available in most cases is not in line with the present day effluent requirements.

The situation in regard to industrial wastes is even more serious. Of the 16 plants studied, 9 failed to meet the present day B.O.D. requirements and 5 plants the coliform requirements. At present the 9 plants failing to meet the B.O.D. requirements have either no treatment or lagooning as the only treatment process. Most of these wastes have either a high concentration of B.O.D., are difficult to treat or no known methods of treatment are available. In addition, the large volumes of many of these effluents make the problem of conforming these plants to the present day requirements one of major proportions.

e. Conclusions

1. The volume of flow from municipal and industrial plants amounted during the survey to 102 mgd. It is expected that a considerable amount of cooling waters will be discharged directly to the river or its tributaries, leaving an estimated 76.5 mgd to be discharged into a trunk sewer, namely about 42.5 percent from municipal sewers and 57.5 percent from industrial plants.

2. On the basis of adjusted flow values and all analytical data available, the suspended solids contribution by municipalities

and industries is calculated to be 43 and 57 percent respectively, whereas the B.O.D. contribution is calculated to be 52.5 percent for municipalities and 47.5 percent for industrial effluents not discharged into municipal sewers.

3. The organic pollution produced amounts to a population equivalent of over 1,100,000.

4. The operation of municipal treatment plants, as measured by B.O.D. and suspended solids reductions, was generally in accordance with the design of the plants, but only 6 of the 22 municipal plants met the present requirements.

5. With the possible exception of a few of the existing municipal plants none will meet the higher requirements imposed for reduction of pollution of the receiving waters.

6. Only 5 of the industrial effluents discharged meet present B.O.D. and coliform organisms requirement. In addition, other requirements must be met for disbharge of industrial effluents, so that probably only two of the industries, discharging small amounts of waste, would meet all requirements.

V. Tidal and Non-Tidal Currents in Raritan Bay

The chemical and bacteriological results obtained were plotted on a series of maps to indicate densities and variations in the condition of the bay at various sampling points. The data for each sampling period was plotted to obtain information regarding the degree of variations. In addition, the chemical and bacteriological results were averaged and plotted on similar maps to indicate the general condition of the bay. After the results had been plotted on some 50 maps it was evident that they could be used effectively to show the behavior of the tidal and non-tidal currents, to indicate the fresh and salt water mixing, and to allow calculations to be made concerning the behavior and effect of the effluent from a treatment plant discharged at a given point in the bay.

a. Tidal Currents

1. Direction

A few maps showing chloride and iron contours are included in the report to show some of the typical water movements within the head end of Raritan Bay. Individual contour maps for chlorides and coliform organisms were prepared for each days run, and for both top and bottom samples. Coliform contours showed the same general configuration as chloride contours, so for illustration chloride contours are used since they show more clearly other fresh water movements, particularly water discharged by Cheesequake Creek.

Contour maps can be used to show movement of one type of water through another of different chemical characteristics.

The movement of the river water is shown directly by the "points" or rounded end of the contour. The narrowness or the sharpness of the points in general, indicates the intensity of the water movement.

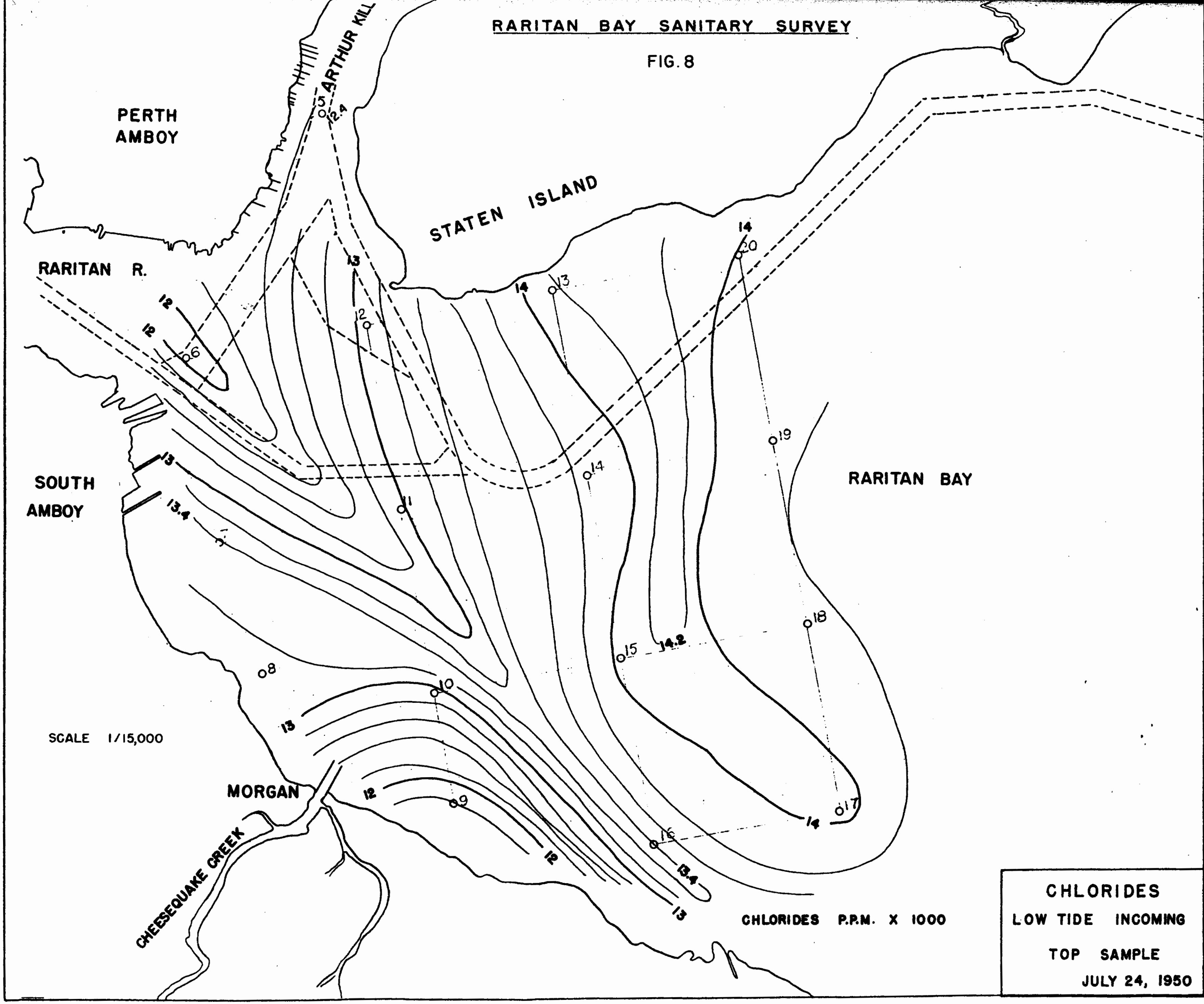
The movement of the water at low tide is shown by the July 24 and 26 chloride contour maps. (Figs. 8,9, 10 and 11) In general, the surface maps show that the river moves straight out into the bay keeping to the New Jersey side. The movement of the bottom water is less pronounced. On July 26 the projection of the river water into the bay was spread out, while on July 24 the bottom water swerved toward the middle of the bay, with considerably less movement that the top waters.

These differences in the magnitude of movement between top and bottom waters are due to the fact that the water coming out of the river is less dense than that in the bay and tends to ride out in the bay on the surface. The pronounced leftward turning of the bottom water on July 24 was typical of other days. This bending of the water mass could be brought about by the leftward turning of the deep water channel, causing bottom flows to bend in the direction of the channel.

The low tide contour maps show the average condition of the bay between the time of low tide for the last range (stations 16 - 20) and 2 hours after low tide for the first range (stations 6 - 8). High tide contour maps show the average condition of the bay from 2 hrs. (at first range) to 4 hours (at last range) after high tide in the bay. (Figures 12 and 13).

RARITAN BAY SANITARY SURVEY

FIG. 8



CHLORIDES

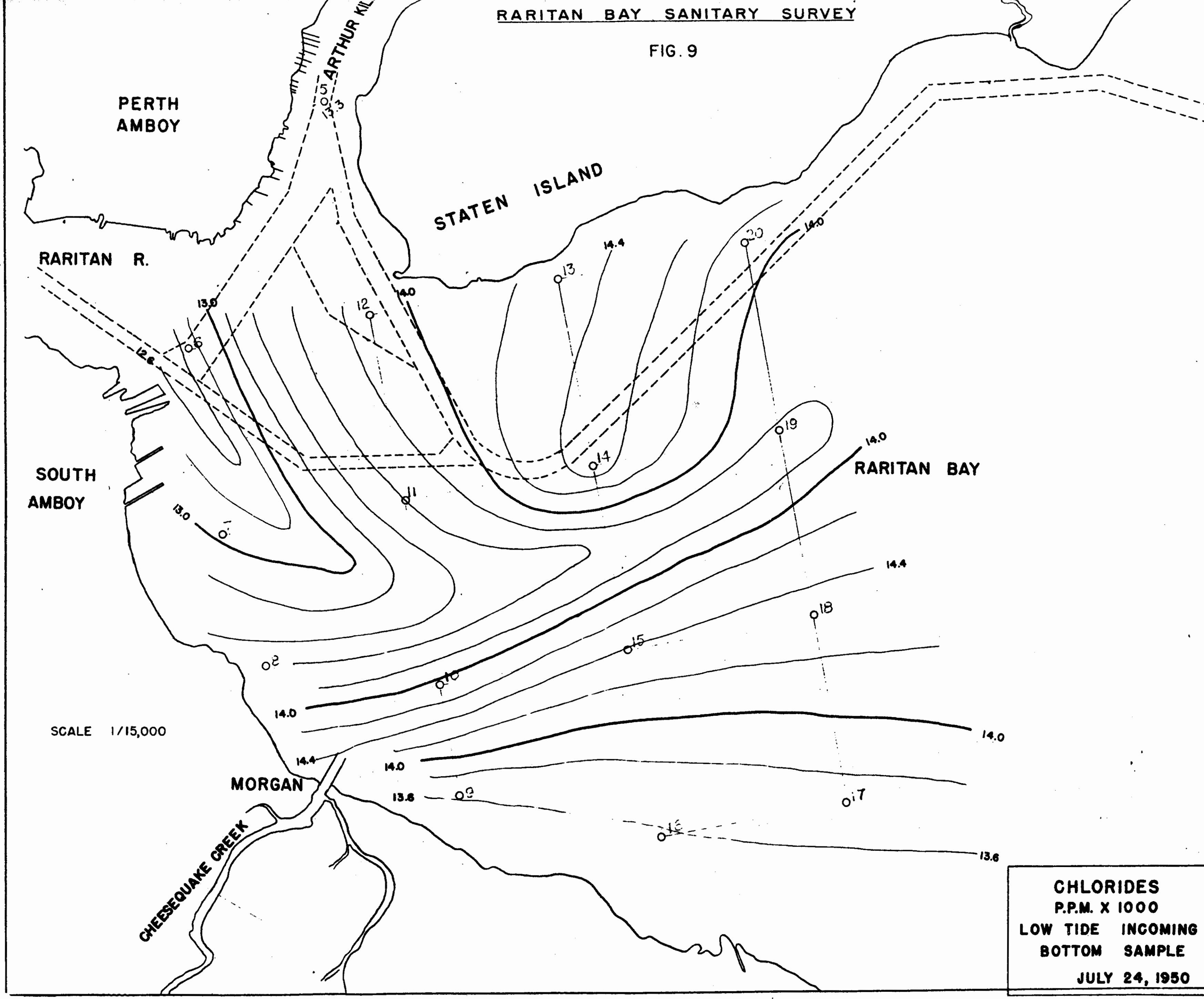
LOW TIDE INCOMING

TOP SAMPLE

JULY 24, 1950

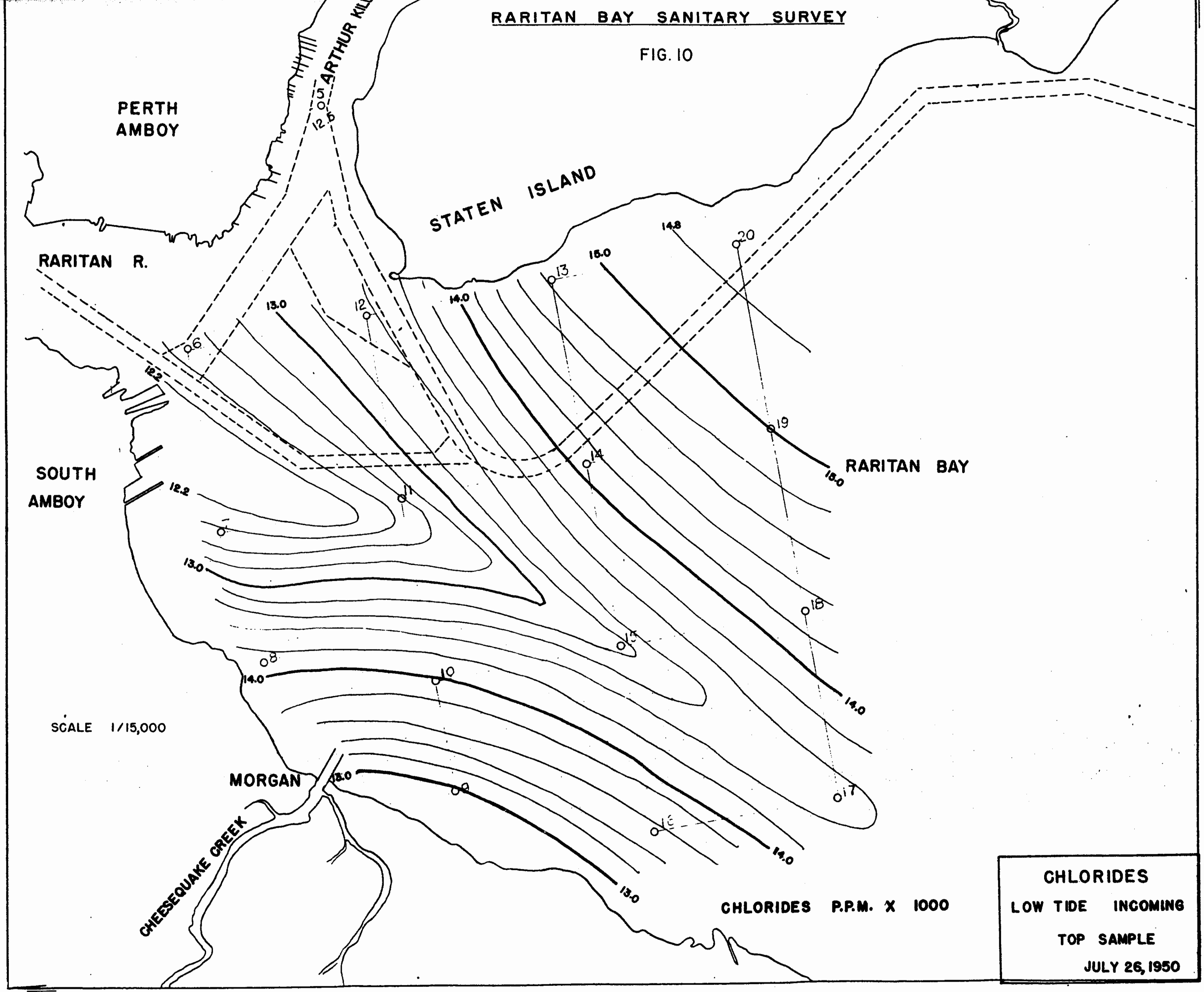
RARITAN BAY SANITARY SURVEY

FIG. 9



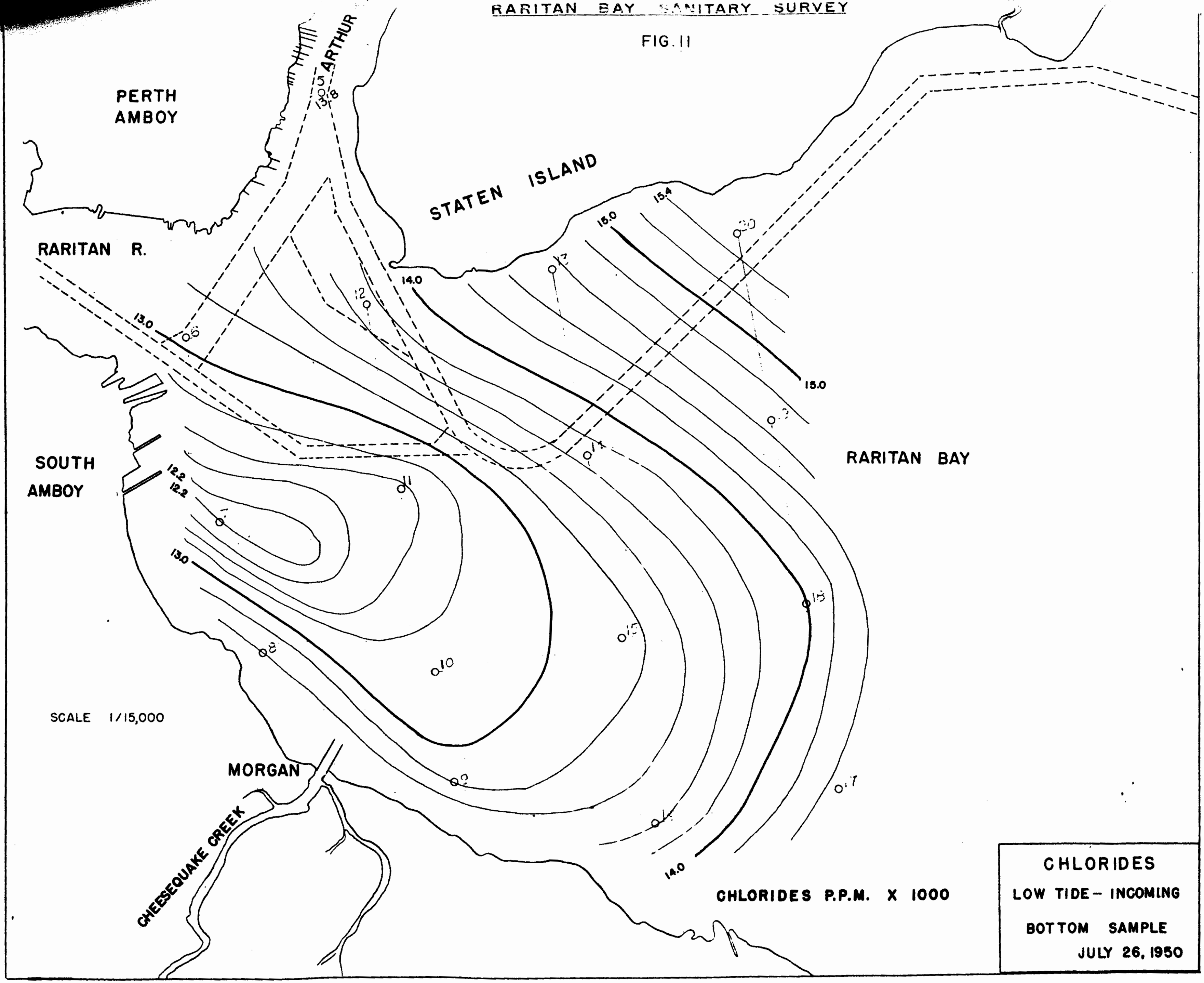
RARITAN BAY SANITARY SURVEY

FIG. 10



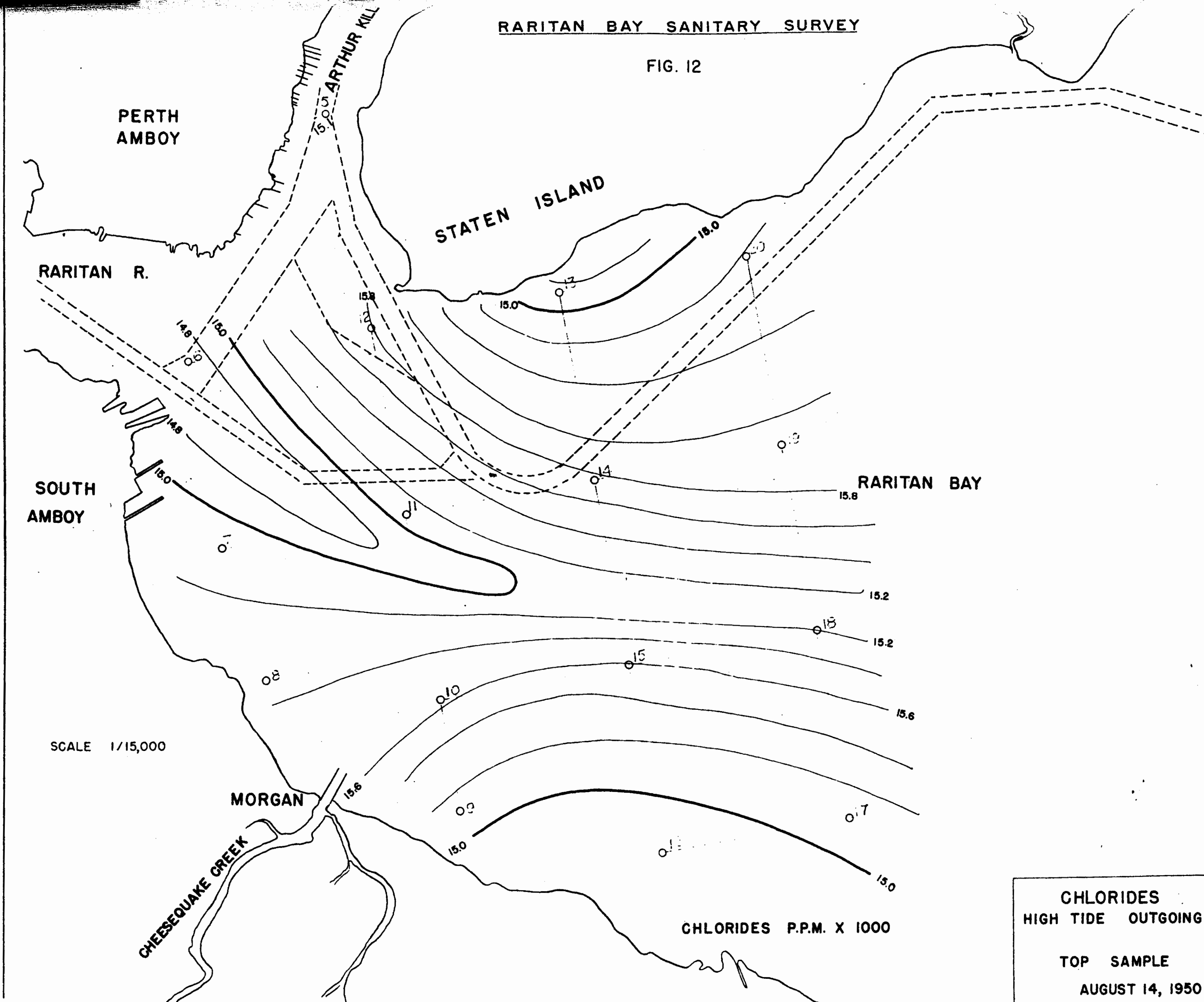
RARITAN BAY SANITARY SURVEY

FIG. 11



RARITAN BAY SANITARY SURVEY

FIG. 12



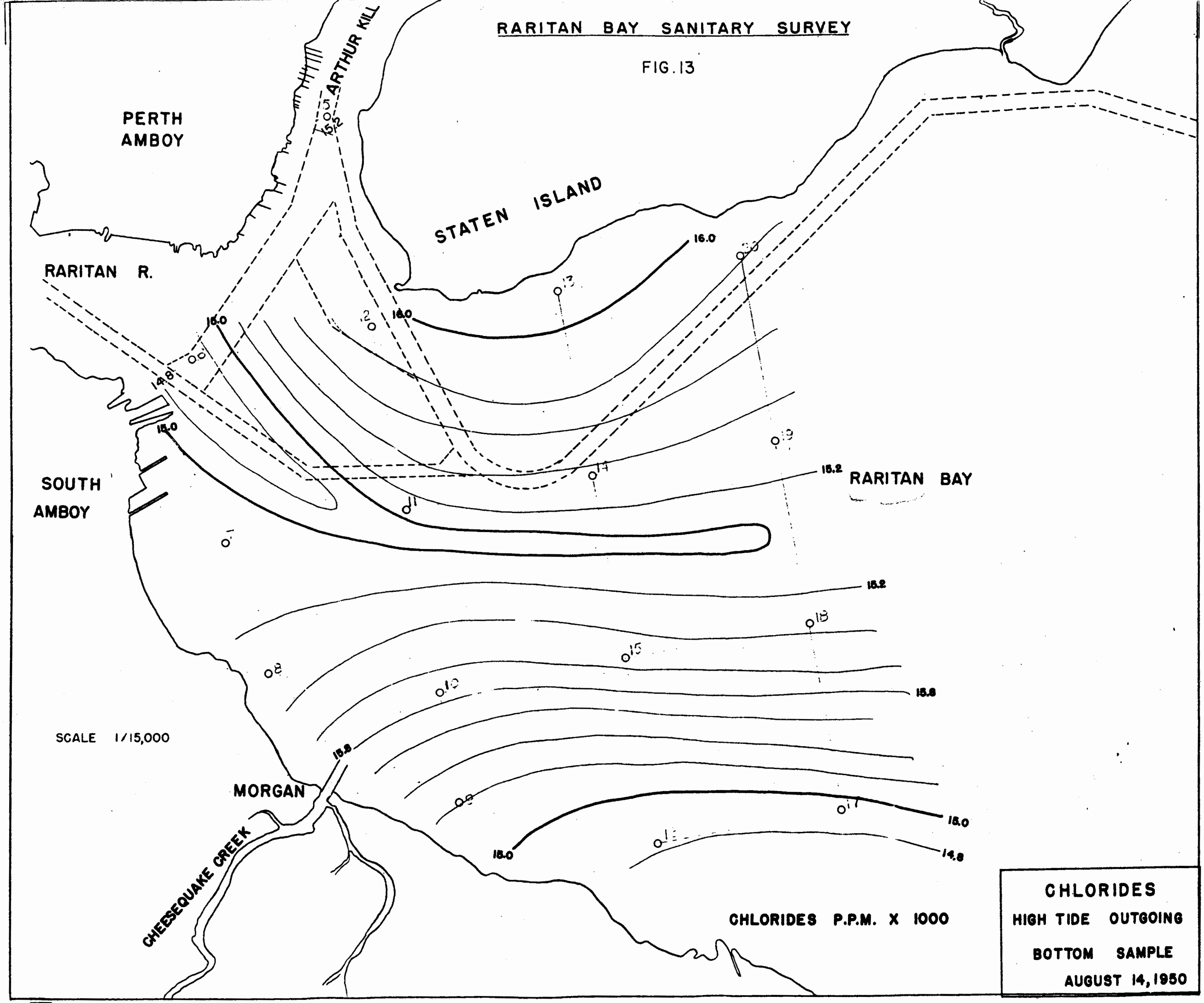
CHLORIDES
HIGH TIDE OUTGOING

TOP SAMPLE

AUGUST 14, 1950

RARITAN BAY SANITARY SURVEY

FIG. 13



Because of the difference in time, the high tide contour maps show the condition of the bay at about the middle period of the ebb tide. Hence, they show a definite movement of river water within the head end of the bay. In general, the same type of movement is shown by all maps, except that at half ebb tide the river water protrusion is less and the tendency of the river water to turn toward the center of the bay is more pronounced.

The veering of the fresh water stream in the bay is the result of the curving of the shipping channel, which bends generally north-east. Since the velocity of the fresh water stream gradually increases during ebb tide the curving or veering of the fresh water stream is more pronounced at the beginning of the ebb tide than at the end of the ebb tide.

The veering of the fresh water stream is more pronounced at the bottom of the bay, because of the effect of the depth of the channel. The deeper channel has a tendency to guide the fresh water stream.

All contour maps for chlorides show the effect of the Cheesequake Creek on the salinity in the bay. In every case there is an increase in salinity until a maximum contour is reached and then a decrease in salinity toward the New Jersey shore. These decreasing salinity lines all tend to turn toward the Cheesequake Creek Inlet.

The apparent effect of the Cheesequake Creek on the salinity of the bay along the shore is great because the tidal currents in this shore area are very weak. Tidal current charts for New York Harbor of the coast and Geodetic Survey show practically no movement in this area on either the flood or ebb tides.

2. Velocity

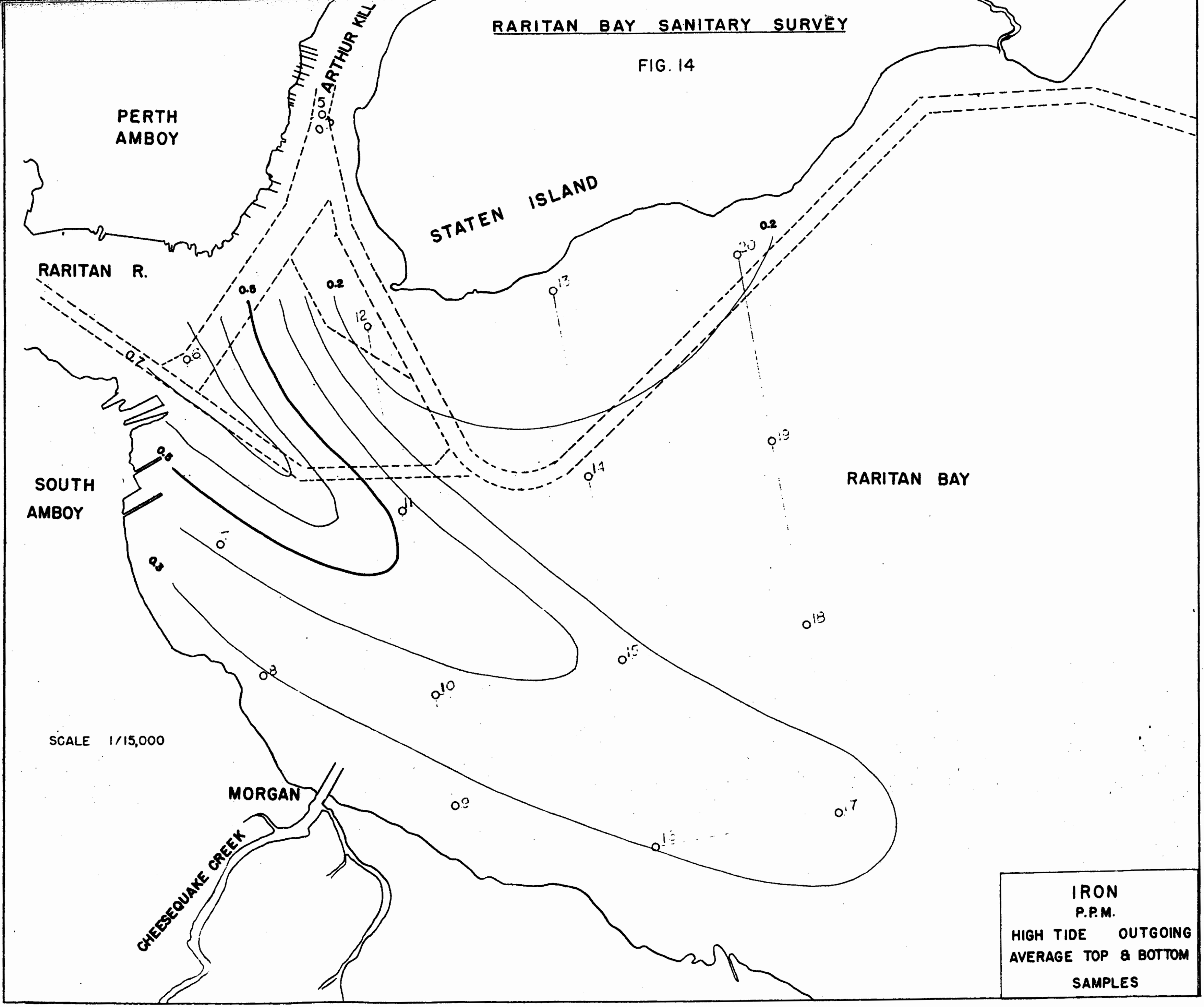
The average velocity of currents in the bay can be computed if the average distance and time interval between corresponding contours on high and low tide contour maps is known. Contour maps of the high and low tide average salinities are not as suitable for the purpose of velocities than the iron determinations. This is because there are three major sources containing fresh water at the head of the bay, namely the Raritan River, Arthur Kill and Cheesequake Creek. Contour maps for average iron content at high and low tides show a much clearer picture of Raritan River water movement since the Raritan River is the only major source of iron entering the bay.

Measurements on the average iron contour maps (Figs. 14 and 15) show a seaward movement of water on the ebb tide of 11,000 ft. in 3 hours or approximately 3600 ft./hr. between the second and fourth ranges. Measurements on the chloride contour maps show a fresh water extrusion of 18,000 to 24,000 ft. in six hrs. or an average velocity for the entire 4 ranges of about 3500 ft./hr.

From a calculation of the total flow of water past the river mouth on ebb tide it was determined that the average velocity would be approximately 2,000 ft./hr. and that the maximum velocity would be 5,400 ft./hr. This gives a rather

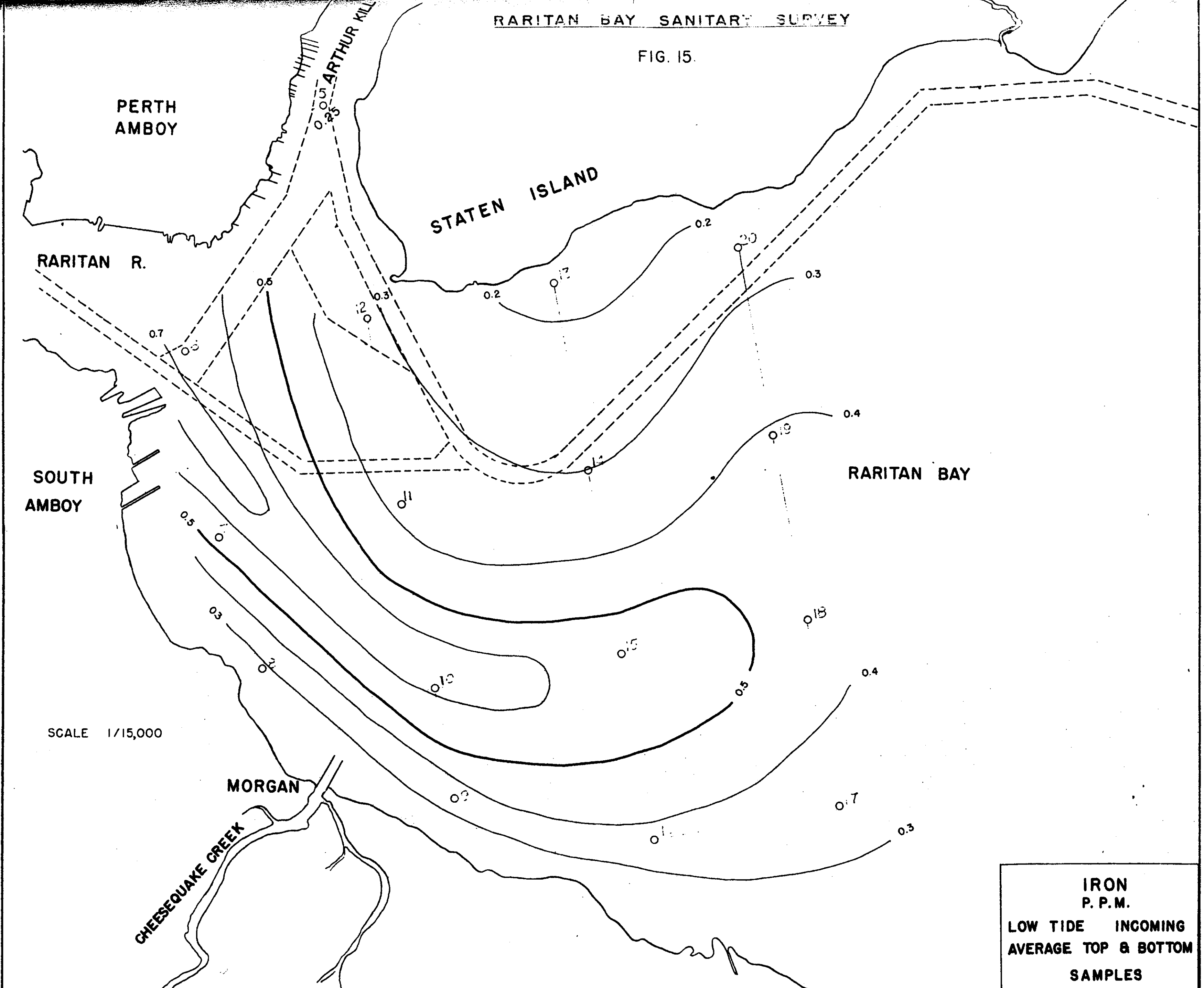
RARITAN BAY SANITARY SURVEY

FIG. 14



IRON
P.P.M.
HIGH TIDE OUTGOING
AVERAGE TOP & BOTTOM
SAMPLES

FIG. 15.



IRON
P. P. M.
LOW TIDE INCOMING
AVERAGE TOP & BOTTOM
SAMPLES

good check on the entrance velocity of the river water into the bay on ebb tide as calculated by two entirely different methods. The results also check with the average maximum current of 9,000 ft./hr. (U.S. Coast and Geodetic Survey - Current Tables 1950) at the Victory Bridge where the main river channel is narrower.

On the basis of the various calculations it appears that the river has an excursion of at least 3 miles into the bay on ebb tide and that the maximum seaward velocity ranges from about 5000 ft./hour at the river mouth to about 2000 ft./hr. at the 4 mile point.

b. Tidal Excursions

The tidal excursion, or the theoretical back and forth movement of the water between tides (tidal prism flow) can be computed for any part of the bay if the area, depth, width and tide difference is known. A tidal prism contains a volume of water equal to that required to fill the tidal void between the land and the shore side of the tidal prism. This volume includes all the water required to fill the tidal areas of the rivers and estuaries as well as the bay itself.

Theoretically with even distribution of velocity across the bay, the water would move back and forth the length of the prism with each tidal change. This back and forth movement is called the "tidal excursion."

c. Non-Tidal Excursion (Seaward)

There is a continuous discharge of fresh water into the bay, most of which comes from the Raritan River. This fresh water must be carried seaward to the ocean. The net daily movement of fresh water toward the ocean, assuming uniform distribution across the bay, is called the non-tidal excursion. Because of the large volume of dilution water in the bay compared with the fresh water flow this theoretical net seaward movement is small, amounting to less than a quarter of a mile per day.

d. Non-Tidal Salt Water Drift (Landward)

In order to maintain a uniform average salt content in the bay there must be a net landward drift of salt water from the ocean to the head of the bay. Since the salt content of the backward drifting water decreases as it moves toward the head of the bay the volume of drifting water must increase to maintain a uniform salt content. The salt water drift varied from 75 percent of the fresh water river flow at Sandy Hook to 100 percent of the fresh water flow at the head of the bay.

Thus, the average salt water landward drift is slightly less and in the opposite direction to the fresh water non-tidal excursion.

e. Magnitude of Theoretical Tidal and Non-Tidal Movement

To determine the theoretical movements discussed above, calculations were made for three tidal prisms: Prism #1 extends seaward from the mouth of the Raritan River; Prism #2 extends from the two mile line (approximate location of proposed distribution outfall) back toward the head of the bay; while Prism #3 extends from the 2 mile line seaward toward Sandy Hook.

These three prisms were chosen because they appear the most critical to the problem of Raritan Bay Pollution. Prism #1 is the most polluted part of the bay, while prisms 2 and 3 are those two immediately landward and seaward of the proposed effluent discharge point.

The following compilation shows the theoretical tidal excursion, the average non-tidal fresh water excursion, and the non-tidal sea-water drift for each of the three prisms.

	Average Tidal Excursion	Average Non-Tidal Fresh Water Excursion Seaward	Average Non-Tidal Sea Water Drift Landward
Prism 1	3800 ft/tide	1000 ft. per day	300 ft/day
Prism 2	5000 ft/tide	800 ft. per day	180 ft/day
Prism 3	5000 ft/tide	700 ft. per day	125 ft/day

According to these calculated movements it takes approximately an average of 11.5 days for fresh water to move (10,500 feet) from the mouth of the river to the two mile point proposed for the effluent discharge. The non-tidal landward drift of sea water is even slower, and it requires more than 30 days for sea of bay water to move backward from the 2 mile point to the mouth of the river.

The theoretical average tidal excursions are much greater in magnitude than the average non-tidal movements. Since the tidal excursions occur in approximately six hours the average tidal excursion velocity is approximately 800 feet per hour, while the non-tidal seaward and landward movements are about 40 ft./hour and 10 ft./hour respectively.

Because the tidal motion is from 25 to 100 times faster than the non-tidal movements, the non-tidal movements are obscured by the reversing tidal flows. Calculations for the theoretical non-tidal movements are useful and necessary to show the average time required for sea and fresh waters to migrate within the bay.

f. Fresh and Sea Water Mixing

Examination of the contour maps and calculations of the velocity of the river water entering the bay on the ebb tide has shown that the velocities of the outflowing river water are from six times the average excursion velocity at the mouth of the river to at least twice the tidal excursion velocity at the two mile point.

This means that even with an incoming tide a portion of the protruding river flow at the head of the bay will continue seaward. The velocity will be reduced by the landward tidal movement but the net movement will be outward.

The total or net movement across the bay is backward on the flood tide. Since the center portion of the water continues forward, the portion of the bay near the shores move backward faster than the average tidal excursion velocities.

This increase in backward tidal movement near the shores is indicated by the fact that the shore contours are always swept backward like the point of an arrow. If on the flood tide the backward tidal movement was uniform across the bay, then it would be expected that the points of the contour lines would be reversed or at least show a landward bending.

The protrusion of river water three to four miles into the bay means that the mixing of the river and bay water takes place to a large extent far out in the bay where there is a large volume of dilution water and not within the narrow confines of the bay near the mouth of the river, as assumed for the theoretical calculations.

It is probably more for this reason than any other that the condition of the lower river and upper bay is better than was expected. If the river water mixed with the bay water gradually, as assumed theoretically, the B.O.D. of the fresh water portion at Perth Amboy (Victory Bridge) sampling station would have been four times that which was actually found. The indicated age of the fresh water portion would have been six days instead of 12 days.

From the calculated and observed results it can be concluded that the natural river currents projecting out into the bay reduce the pollution density of the bay and river in the Amboy areas by 50 percent to 75 percent. Aside from the fact that the pollutional matter discharged into the Raritan bay is to be treated, the simple conveyance of the wastes two miles in the Bay would further reduce the pollution effect in the Amboys area.

g. Effluent Mixing

The fresh water in the bay area studied varied from 17 percent at high tide to 27 percent at low tide. With a volume of waste water flow of 100 mgd and the total river flow 225 mgd (the average for period studied, corrected for additional fresh water below Bound Brook) the polluted water in the mouth of the bay varied from 7.5 percent (at high tide) to 12 percent (at low tide) of the total water. Hence, the maximum volume of polluted water during the dry period distributed evenly was about one-eighth of the total water in the Amboy's area.

Calculations show that if the effluent from a sewer discharging 100 mgd at the two mile point is distributed evenly across the bay (which would constitute maximum pollution conditions), the maximum effluent concentration at the head of the bay (Amboys' area) would amount to 2 percent of the total water. Under these conditions it would require 30 days for the polluted water to reach the Amboy's area. Under average conditions of flow the concentration of polluted water would amount of 1 percent. Hence, location of an outfall at the two mile point would reduce greatly the pollution in the Amboy's area.

The fact that at maximum pollution conditions it would require 30 days for the effluent to reach the mouth of the bay is of particular importance. Under natural conditions, considerable self-purification takes place in bodies of fresh and salt water. The intestinal bacteria die and the organic material is oxidized. Numerous studies show that the self-purification over a period of 30 days results in a reduction of pollution of more than 90 percent. Is is clear, therefore, that the pollution concentration in the Amboys area would be extremely small even if no treatment of the wastes were provided. Since it is proposed to treat all wastes in a treatment plant, the numbers of intestinal bacteria and amounts of organic solids would be reduced as compared with present conditions. This tends to reduce the pollutional concentration still further.

The results show that the river forces itself a considerable distance into the bay. When the effluent of the proposed treatment plant is discharged at the proper point, advantage can be taken of the natural seaward currents to carry the effluents farther out and allow mixing with the bay water even farther than would be the case if a diffusion area were formed near the outlet. Moreover, when the effluent mixes farther out in the bay with an increased volume of bay water the possibility of landward movement of the mixture would be still less than indicated on the maps.

The exact location of the effluent outfall and the design of an effluent distribution system should be carefully considered to take advantage of the natural conditions in the bay. If this is done contamination of the bay by the treated effluent will be insignificant.

h. CONCLUSIONS

Study of the large number of charts and calculations made lead to the following conclusions:

1. The major portion of the river flow protrudes straight out into the bay and keeps to the New Jersey side. The center of the flow is about 6,000 feet, or more than a mile, off-shore.

2. Part of the river flow, particularly that near the bottom, veers northward to the middle of the bay.

3. The river flow on ebb tide has an excursion of at least 3 miles out into the bay.

4. The maximum velocity of the protruding river water varies from 5,000 feet per hour at the river mouth to 3,000 feet per hour at a point 3 miles out in the bay.

5. Compilation of three tidal prisms (one at the head of the bay, one immediately landward of the two mile line proposed for treated effluent discharge point, and one immediately seaward of the two mile line) together with other data show that:

a. The average tidal rise in the river up to New Brunswick amounts to about 4.7 feet. This volume of water was equivalent to 16 times the average river flow during the surveys. Since the tidal changes occur twice a day, the average daily volume of water passing seaward through the mouth of the river was approximately 32 times the fresh water river flow.

b. The volume of sea water entrained in the seaward flow varied from 3 times (at the mouth of the river) to about 5 times (at the 4 mile point in the bay) the volume of fresh water.

c. The tidal excursion and the non-tidal seaward excursion varied:

	Tidal Excursion ft/day	Non-Tidal Excursion ft/day
Prism 1	3,800	1,000
Prism 2	5,000	800
Prism 3	5,000	700

d. The average flushing time for the river during non-tidal excursion was eleven days up to the two mile point or the approximate point of treated effluent discharge.

e. The percentage fresh water in the area studied varied from 27 to 17 percent.

f. If the proposed sewage plant effluent, amounting to 100 mgd, was discharged into the bay at the mouth of the river, the effluent would constitute from 12 to 7.5 percent of the total volume of water at that point.

g. If the treated effluent, amounting to 100 mgd, is discharged into the bay at approximately the proposed two mile point, the maximum effluent concentration at the head of the bay will be 2 percent, provided proper seaward dispersion is practiced.

h. The average time required for any part of the effluent discharged at the two mile point to drift to the head of the bay is about 35 days.

6. Non-tidal seaward velocities of fresh water tend to be less than reversing tidal velocity. (This conclusion is

based upon the results obtained concerning time of passage, tidal and non-tidal excursions and percent river water in the bay computed for the average movement of fresh and salt water and assuming that the fresh water mixes uniformly with the salt water).

7. Within the four mile area of the upper bay the seaward velocity of the fresh water is 2 to 4 times the reversing tidal velocities.

8. Because of the high seaward velocities of the Raritan River the point of dispersion of river water extends out into the bay where a large volume of dilution water exists.

9. The bay area studied shows considerably less pollution than would be expected from calculations based only upon theoretical considerations of fresh water movement within the bay. The factor of self-purification during the time required for movement of fresh water movement plays an important role.

10. Advantage should be taken of desirable seaward velocities to carry the treated effluent farther out into the bay for dispersion with larger bodies of water.

11. Location of the treated effluent outfall should be in the neighborhood of the proposed site about 2 miles into the bay, utilizing the force or velocity of the effluent and the existing protruding river flow.

12. With proper location of the outfall and discharge of the treated effluent the amount of effluent which could return to the head of the bay would be negligible.

13. In general, the results of the survey concerning tidal and non-tidal flows are in accord with other investigations, including those made by the Woods Hole Oceanographic Institution.

VI. Bathing Beach Survey

The bacteriological condition of the beaches in the Raritan Bay was studied by determining the numbers of coliform organisms present in surf samples. The samples were taken on July 24 and 26, 1950 at different cycles of the tide. Each beach water was sampled 4 times in duplicate, or a total of 176 samples for 22 beaches.

The average numbers of coliform organisms in the 4 samples from each sampling station are given in Table 21, together with a description of the locations where the samples were taken. The average number of coliform organisms ranged from a maximum of 74.6 to a minimum of 1.1 per ml. in the surf sample waters taken from the individual beaches. The two beaches with the highest numbers of coliform organisms were found to be Cliffwood Beach and Perth Amboy (State Street) Beach. The lowest numbers of coliform organisms were found in the water at Union Beach (Pine Street) and Keansburg (Lawrence Ave.) Beach. The surf samples of the other beaches showed coliform concentrations varying from 1.4 to 16.1 per milliliter. The variations of the coliform concentrations from 1.1 to 74.6 tends to indicate the influence of local conditions.

The tentative working standard used by the N. J. State Dept. of Health for bathing beaches in the Raritan Bay area is 24 coliform organisms per ml. Under this standard the Cliffwood and Perth Amboy beaches are unsuitable for bathing. The Cliffwood beach is outside the bay area surveyed to determine

TABLE 21

Coliforms in the Surf Samples from Various Beaches in the

Raritan Bay

(Average M.P.N. per ml. of 4 Samples Taken on July 24 and 26 at Different Cycles of the Tide)

Beach		Ave. Coliforms per ml.
Keyport		
Beach at Main Dock		2.6
Rear Keyport Yacht Club		2.2
Matawan Creek		15.5
Cliffwood Beach	Below Restaurant	74.6
Charlies Beach	Opp. Refreshment Stand	11.3
Seidlers Beach	Opp. Restaurant	6.4
Lawrence Harbor	Opp. Restaurant	7.3
Morgan's Beach	Opp. Bath House	9.0
South Amboy	Gorden St.	11.0
Perth Amboy	State St. Beach	52.0
Union Beach	Pine St.	1.1
Keansburg		
Laurel Ave.		2.1
Carr Ave.		7.3
Bayview Ave.		16.1
Lawrence Ave.		1.3
Ideal Beach	Brant Ave.	2.3
Leonardo	Concord St.	1.4
Atlantic Highland		
Free Beach		6.3
Richard's		8.0
Highlands		
Atlantic St.		2.6
Miller St.		7.3
Rumson		
Lafayette St.		15.0

the conditions of the bay, but it would seem doubtful that the pollution of the river is responsible for the condition of this beach. Examination of the contour maps for the average coliform organisms found during the bay survey (Fig. 2) indicate that conceivably a part of the beach pollution is caused by the Raritan River flowing past this station. However, during the survey of municipal sewage treatment plants, the Perth Amboy plant did not meet the N. J. State Department of Health requirements.

The average coliform results plotted in Fig. 2 show that the greatest density of organisms in the bay extend as a tongue from the mouth of the river in a southeasterly direction towards the New Jersey shore with a steep gradient from the center of the tongue toward the periphery. At the outermost edge of the tongue at the bay sampling station nearest the New Jersey shore the coliform density was 16 per ml. The surf samples taken from the beaches along this shore as indicated in Fig. 2 show the possibility that the pollution at the beaches may be influenced by the periphery of the tongue of pollution in the bay derived from the river.

The removal of pollution from the river and discharge of a treated effluent about 2 miles out in the bay will reduce the pollution of the beaches in the upper bay area and beach pollution would be subject only to local conditions.

a. Conclusions

A survey of the bathing beaches within the Raritan Bay area shows that:

1. The number of coliform organisms were higher on two beaches than the tentative working standard allows for beaches suitable for bathing purposes.

2. The pollution of a number of surf waters are partly the result of local origin and probably partly caused by the pollution of the Raritan River and other tributaries to the bay.

3. Removal of pollution from the river by the construction of a trunk sewer and treatment plant will reduce the beach pollution in the upper bay.

4. Location of an effluent outfall about 2 miles in the bay will result in outward movement and high dilution of the effluent and prevent the effluent from reaching the beaches in the lower bay.

VII. Raritan Bay Pollution in Relation to Shellfish

a. Areas Open for Shellfishing

Most of the area of Raritan Bay is closed to the taking of shellfish because of excess pollution of the waters as measured by the numbers of coliform bacteria in the water. One area approximately 3 miles long and 4 miles wide, midway between Perth Amboy and Sandy Hook, has been opened, although shellfishing is still prohibited within approximately 1,000 yards from shore. (Fig. 16).

The major sources of bacterial pollution can be roughly classified as:

1. Raritan River
2. Arthur Kill
3. Shore Pollution (Staten Island, New Jersey)
4. Lower N.Y. Bay (contributed through the Narrows, Rockaway Inlet, etc.)

From a study of Fig. 16 it appears that the pollution of the upper Raritan Bay is influenced by the Raritan River, that the pollution of lower Raritan Bay is influenced by pollution contributed from Lower New York Bay and that the pollution along the shore bounding the open shellfish area is contributed from bordering shore communities. Although there may be some overlapping of pollution influence, particularly along the shore, the preceeding statements are considered generally correct, otherwise there would be no area with low enough coliform bacteria counts to be kept open for shellfish.

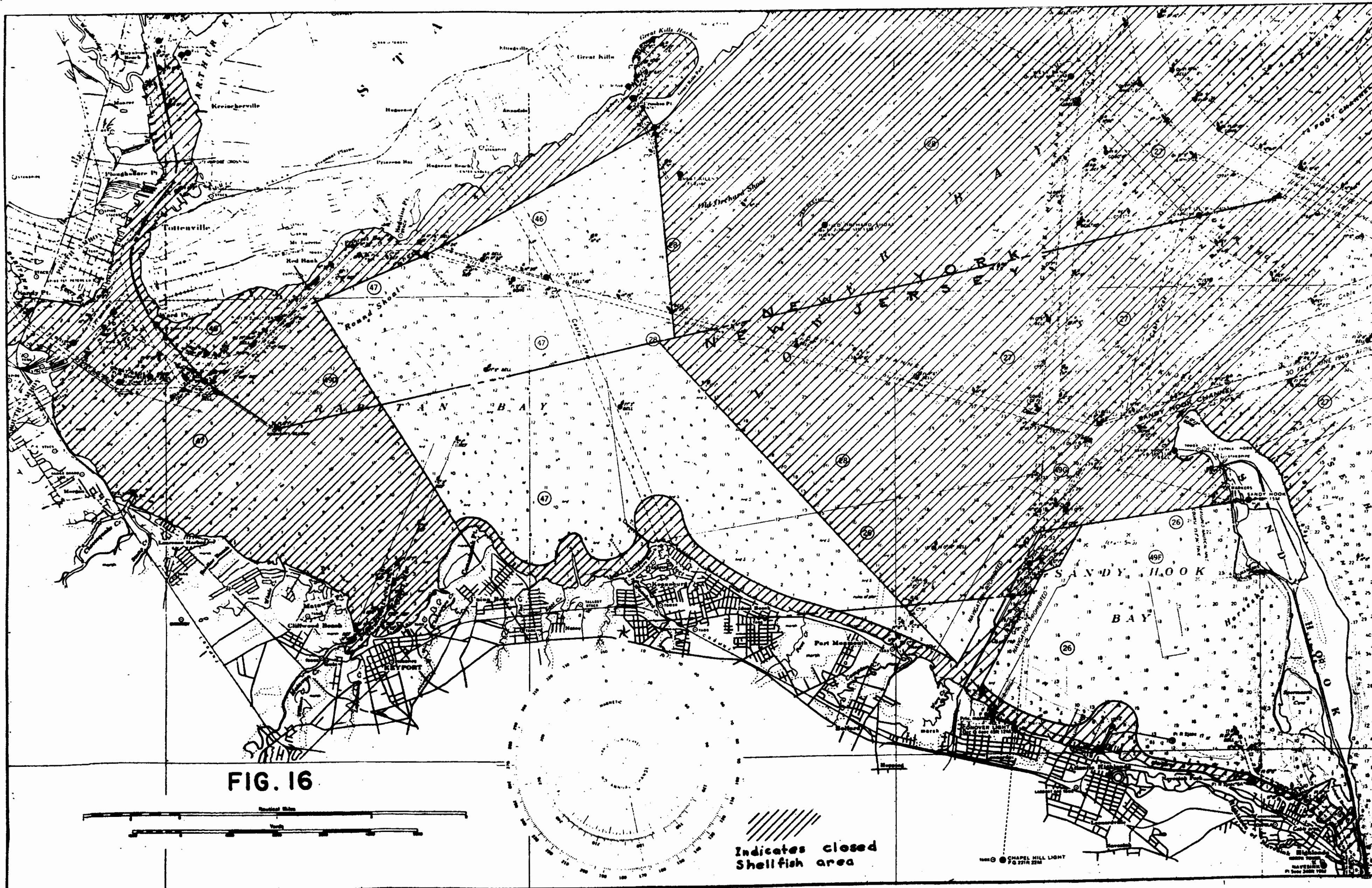

Indicates closed Shellfish area
RARITAN BAY
LOWER NEW YORK BAY
NEW JERSEY
NEW YORK
SANDY HOOK BAY
SANDY HOOK
KEYPORT
Port Monmouth
Tottenville
Great Kills
Great Kills Harbor
Kreischerville
Red Bank
Romer Shoal
Old Orchard Shoal
SANDY HOOK CHANNEL
Cliffwood Beach
Matawan
Keansburg
Belford
Atlantic Highlands
Highlands
CHAPEL HILL LIGHT
NAVIGATION PROHIBITED
marsh

FIG. 16

In order for the open area to have a consistently low coliform bacteria count, the bacterial pollution contributed from the Raritan River appears to be diminished by death and dilution to a satisfactory point. Once this has occurred, it is impossible for Raritan River bacterial pollution to increase so as to affect the coliform bacteria counts in the lower Raritan Bay area. The same reasoning applies to the influence of coliform bacteria from the Lower New York Bay area on the coliform counts in the upper Raritan Bay.

b. Coliform Bacterial Pollution

The coliform bacterial standards for the taking of shellfish in Raritan Bay have been set at 70 per 100 ml. or 0.7 per ml. by the United States Public Health Service. The average coliform bacteria results of our study made during the summer of 1950 are pictorially shown on the coliform bacteria contour map (Fig. 2). The coliform bacteria counts along the outermost range (Stations 17 to 20) averages about 20 per ml.

This range is about one mile from the edge of the open area, and it would appear from these results that the pollution of the Raritan River has already started to encroach on this open area where the coliform bacteria count is required to be less than 0.7 per ml.

The bacterial pollution of Raritan Bay area surveyed has had a rapid increase in the last 10 years. In a U.S.P.H.S. report of 1912, it was found that the waters west of a line between Great Kills and Point Comfort had a coliform bacteria count of 3 per ml. and those east of this line had a count of

8 per ml.

Studies by N. Y. City in the 1930's and by the U.S.P.H.S. in 1940 (A Report on the Public Health Aspects of Clamming in Raritan Bay - 1941) show that the coliform bacterial pollution in upper Raritan Bay remained practically constant at the 5 to 10 per ml. level. The results for a point comparable to station (11) showed a remarkably uniform coliform bacterial level of 3 to 5 during these years, which is the same as the results of the 1912 survey. From these results it could be concluded that the coliform bacteria level of the upper Raritan Bay remained practically static for a period of almost 30 years. In other words, the increase in the number of sewage treatment plants and the increased volumes of sewage treated was able to counterbalance the increase in population growth. From the present study the coliform bacteria count at station 11 was approximately 100 per ml. or a twenty-fold increase since 1940. Since 1940 the volumes of wastes increased but the treatment did not increase proportionally.

c. Changes in Coliform Bacterial Pollution

According to the results of the 1912 U.S.P.H.S. survey, no area of Raritan Bay would have met the stated coliform bacteria standards for shellfishing. It may seem anomalous, therefore, that certain areas should presently be open to shellfishing when there has been a tremendous increase in the numbers of coliform bacteria in upper Raritan Bay. This apparent incongruity may be explained by the following observations:

1. The influence of the Raritan River on coliform bacteria levels in the bay extends about 4 miles out. Beyond this point sufficient dilution has occurred, and the bacterial death rate has been high enough to make the bay waters satisfactory for clamming.

2. In 1912 the coliform bacteria count in Raritan Bay was largely influenced by the major source of pollution at that time, namely New York Harbor.

3. Since 1940 there has been considerable improvement in the sewage treatment facilities of the shore communities. This tends to have its greatest effect on coliform bacteria counts in the midbay area. Nevertheless, the shore areas, subject to the reduced local contamination, are still closed.

4. Improved sewage treatment facilities in the New York Bay, Long Island area has prevented an increased coliform bacterial effect in the lower Raritan Bay Area.

d. Effect of Trunk Sewer on Shellfishing

If all of the sewage and industrial waste is treated in the proposed treatment plant and discharged approximately at the proposed 2 mile point the following results may be expected from the standpoint of shellfishing: (These statements are made on the supposition that bacterial pollution entering Arthur Kill and other areas under the Interstate Sanitation Commission jurisdiction will be largely eliminated by the time the Trunk Sewer is completed)

1. The offshore area of the upper Raritan Bay will be open to shellfishing because:

a. The major source of coliform bacteria in the upper bay will have been eliminated.

b. The effluent discharged from the proposed Raritan River Sewage Treatment Plant will have a coliform bacteria content approximately that of the shellfishing standards.

2. The upper Raritan Bay shore areas will probably remain closed to shellfishing unless shore communities eliminate the discharge of all untreated or ineffectively chlorinated sewage effluents.

3. The areas closed to shellfishing in lower Raritan Bay will remain closed until the New York City sewage treatment program becomes more complete and shore communities solve their own sewage pollution problems.

e. Conclusions

Construction of a trunk sewer and treatment plant at approximately the proposed 2 mile point will:

1. Improve greatly the bacteriological condition of the upper Bay area now closed for shellfish taking.

2. Result in increasing the open shellfish area in the upper Bay.

3. Will affect to a minor degree the opening of the shellfish area in the lower Bay.

VIII. WATER LOSSES AND SALT WATER ENCROACHMENT

When the trunk sewer and treatment plant is constructed with a distribution outfall about two miles into the Raritan Bay, a portion of the present river flow, consisting of municipal and industrial effluents, will be taken out of the river.

The question has been raised what the effect of removing the waste effluents would have on the volume of river water in the river. A second, and perhaps more important question has been raised what the effect of removing the effluents will have on the salt concentration in the lower section of the river.

The question of possible increase in salinity in the lower river and its effect on the Washington Canal at Sayreville is of particular interest in connection with the valuable well fields for domestic and industrial use in the area adjacent to this section of the river. To maintain an adequate supply of process and cooling waters several manufacturing companies developed the Duhernal water supply at a reported cost of approximately $2,000,000.

A study was made of the probably and maximum loss of water when a trunk sewer is constructed to convey the domestic and industrial waste to a treatment plant located in the lower section of the valley and the effluent from the treatment plant to be discharged into the Raritan Bay.

The problem of salt water encroachment is concerned primarily with the lower Raritan River, whereas the diversion affects on the volume of the river concerns the upper part of the river or non-tidal section as well as the tidal zone.

The problem of water losses and its effect upon the stream can be divided into:

1. The effect of water loss upon the upper section of the river from Raritan Borough to the Enfield (5-mile) Dam.

2. The effect of water loss in the tidal zone from the 5-mile dam to the mouth of the bay.

a. River Flow

The average daily flow for each year in the river recorded by the U. S. Geological Survey varied during the last 20 years from 745 to 1450 million gallons a day. Of greater importance than the average daily flow over a given year are the flows during the dry seasons. The readily available figures for the average flow per day for each month during the years 1945 to 1948 inclusive were as follows:

Average Daily Flow in Millions of Gallons

	1945	1946	1947	1948
January	840	1180	937	915
February	1180	675	540	1800
March	1970	1425	765	1910
April	780	525	760	1540
May	1220	1120	1770	2060
June	533	1620	890	1380
July	1550	1040	475	623
August	885	435	375	705
September	1070	247	255	217

October	420	255	195	195
November	1240	240	1610	330
December	1770	360	577	1530
Average	1130	757	765	1100

The lowest average daily flow for any given month was 195 mil. gals., which occurred in the fall of the year.

b. Waste Flow

The estimated total domestic and industrial waste effluents for 17 municipalities and ten industries, which discharge appreciable quantities of effluents directly into the Raritan River or its tributaries without the use of municipal sewers, is about 100 mil. gals. a day. Of the total volume of effluents discharged about 42 mil. gals. a day is cooling water. Although the total flow in the trunk sewer will probably be materially less than 100 mil. gals. a day because of the separate discharge of cooling waters directly to the river, for calculation and study the total flow to be diverted from the river has been assumed to be 100 mil. gals. a day.

c. Sources of Water

The known sources of water used for domestic and industrial are approximately as follows:

1. Surface water (municipal and private water plants) 34 mgd.

2. Well waters (municipal, municipal and private) 33 mgd.

3. Direct from Raritan (cooling water, etc.) 32 mgd.

d. Water Losses

1. Upper River Zone

The total estimated flow of effluents discharged into the upper zone by all municipalities and industries concerned is slightly over 32 mgd. Of the 32 mgd at least 12 mgd is cooling water. The average daily flow in the river at Bound Brook for any year since 1923 has varied from 650 to 1340 mgd. However, the crucial time is during the fall when the river flow is lowest. The lowest average daily flow for any month ever reported was 130 mgd.

When the trunk sewer is constructed it can be expected that most, if not all, of the cooling water will be discharged directly into the river. Since the total effluents discharged into the river is 32 mgd, of which conservatively 12 mgd is cooling water, it can be expected that as much as 20 mgd may be diverted from the river to the trunk sewer. At the lowest average daily flow for any year the reduction in river flow would amount to 8 percent. Since we are particularly interested in the flow of the river during periods of low flow and taking the lowest average daily flow for any month reported, the reduction in the river flow during the dry period would amount to 15.4 percent.

The Raritan River is what may be called a "flashy" river, with flows varying materially after every rain. With the waste effluents removed from the river and the river restored to the conditions prevailing in the river above the Borough of Raritan and in the Millstone River, it is doubtful whether the reduction in flow would be noticeable. As far as the average yearly flow in the river is concerned above the 5-mile dam, the effect of removing the effluents from the river would be negligible.

It should be borne in mind, also, that extended use of Canal Water, permitted by the appropriate State Authorities, would not decrease the flow in the river, but may result in less use of river water.

2. Tidal Zone

The total accumulative flow of effluents in the tidal zone constitutes about 100 mgd. This total accumulative effluent flow contains about 42 mgd cooling water taken from the river and well supplies.

Recent information obtained and studies made by the Woods Hole Oceanic Institute for the Middlesex Planning Board are available for quantities of river flow and tidal water during a dry period. During the studies of the Oceanic Institute, the entire river flow entering the bay amounted to 375 mgd. It was calculated that if the total waste effluent flow amounted to as much as one-third (125 mgd) of the entire river, the volume of waste effluents would represent from 3 to 5 percent of the tidal water.

Under present conditions the total volume of waste effluents (100 mgd less cooling waters) probably amounts to some 60 to 65 mgd. The reduction of volume in the tidal water caused by the removal of "fresh" water (effluents) would probably amount to about 1.5 to 2.5 percent. Hence, the removal of "fresh" water, from the river would not measurably affect the volume of water in the tidal zone. Moreover, the effluent will be discharged into the bay. Even if the effluents were diverted to another watershed, the volume of water in the tidal zone would be reduced but the fresh water would be replaced by salt water.

e. Salt Encroachment

The removal of effluents from the river and discharge of them in the bay may affect the salinity in the tidal section of the river. Theoretically, any increase in the salinity may conceivably affect the ground water supplies in this area. The question is what would be the effect of removal of the effluents from the river and discharging them after treatment some two miles into the bay.

The effluents removed from the river are not diverted to another watershed but are to be discharged into the bay where the effluents are now flowing. However, let us first consider the most extreme conditions, namely the lowest average daily river flow for any month recorded of 130 mgd at Bound Brook (which does not take into consideration additional fresh water from tributaries such as Lawrence Brook and the South River), and assuming that 65 mgd of waste effluents were taken out of the river and piped to the sea or to the Hudson River, so that it would constitute an absolute loss.

According to the Oceanic Institute's studies the entire river when flowing at a rate of 375 mgd constitutes a volume of about 3 to 5 percent of the upper bay where the proposed outfall would be located. At a river flow of 130 mgd the volume would be only one-third of the water in the upper bay, or roughly from 1 to 1.75 percent. The 65 mgd waste effluent to be taken out would constitute, therefore, about 0.5 to less than 1.0 percent.

During the 1950 survey the chloride content of the water in the Washington Canal at different stages of tide varied from 4,000 to 10,700 ppm. If all the waste effluent would be diverted, the maximum concentration of chlorides, indicating the salt concentration, would increase at high tide from 10,700 ppm to about 10,800 ppm during the lowest average daily flow of any month recorded.

Assuming that the volume of waste effluents was discharged at a rate of 100 mgd during the lowest average daily flow for any month and that the effluent from the outfall close to the river results in reintroduction of part of the effluent into the tidal zone of the river, so that the salt concentration increased as much as five percent at high tide. The chloride content would then increase from a maximum recorded 10,700 ppm to 11,235 ppm. It is doubtful that such a minor increase in salinity in the tide water in the Washington Canal would have any appreciable effect on the adjacent well fresh water field or would constitute a potential danger.

In an effort to determine the effect of complete diversion of the effluent and the effect of discharging the effluent at the approximate place proposed for the effluent outfall by a different method of estimation we have asked Dr. Bostwick H. Ketchum of the Woods Hole Oceanic Institute to calculate the effect of the diversion on the distribution of salinity within the tidal zone of the river with particular reference to the Washington Canal. Dr. Ketchum has graciously consented to make these calculations and has submitted the following report:

" EFFECT OF THE DIVERSION OF PART OF THE RARITAN RIVER WATER INTO A TRUNK SEWER ON THE DISTRIBUTION OF SALINITY WITHIN THE RIVER.

It has been proposed to build a trunk sewer in the Raritan River Valley which would collect sewage from the various industries and municipalities along the shore, and to discharge the effluent in Raritan Bay at a location about 1-1/2 miles off South Amboy. The effect of this diversion on the distribution of salinity within the river has been calculated using the minimum average monthly flow of 1948. The method of calculation is based upon the tidal exchange concept previously described by the author[1].

Three different conditions have been considered, namely:

1. The distribution of salinity predicted for the minimum average monthly river flow during 1948 (11×10^6 ft.^{3} per tidal cycle).

2. The distribution of salinity predicted for the minimum river flow minus an expected diversion of 100 million gallons

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1) The exchanges of salt and fresh waters in tidal estuaries. submitted to Journal of Marine Research. Unpublished. The flushing of tidal estuaries. Sewage and Industrial Wastes. To be published March, 1951.

per day in a trunk sewer, giving a resultant river flow of 4 x 10^6 $ft.^3$ per tidal cycle.

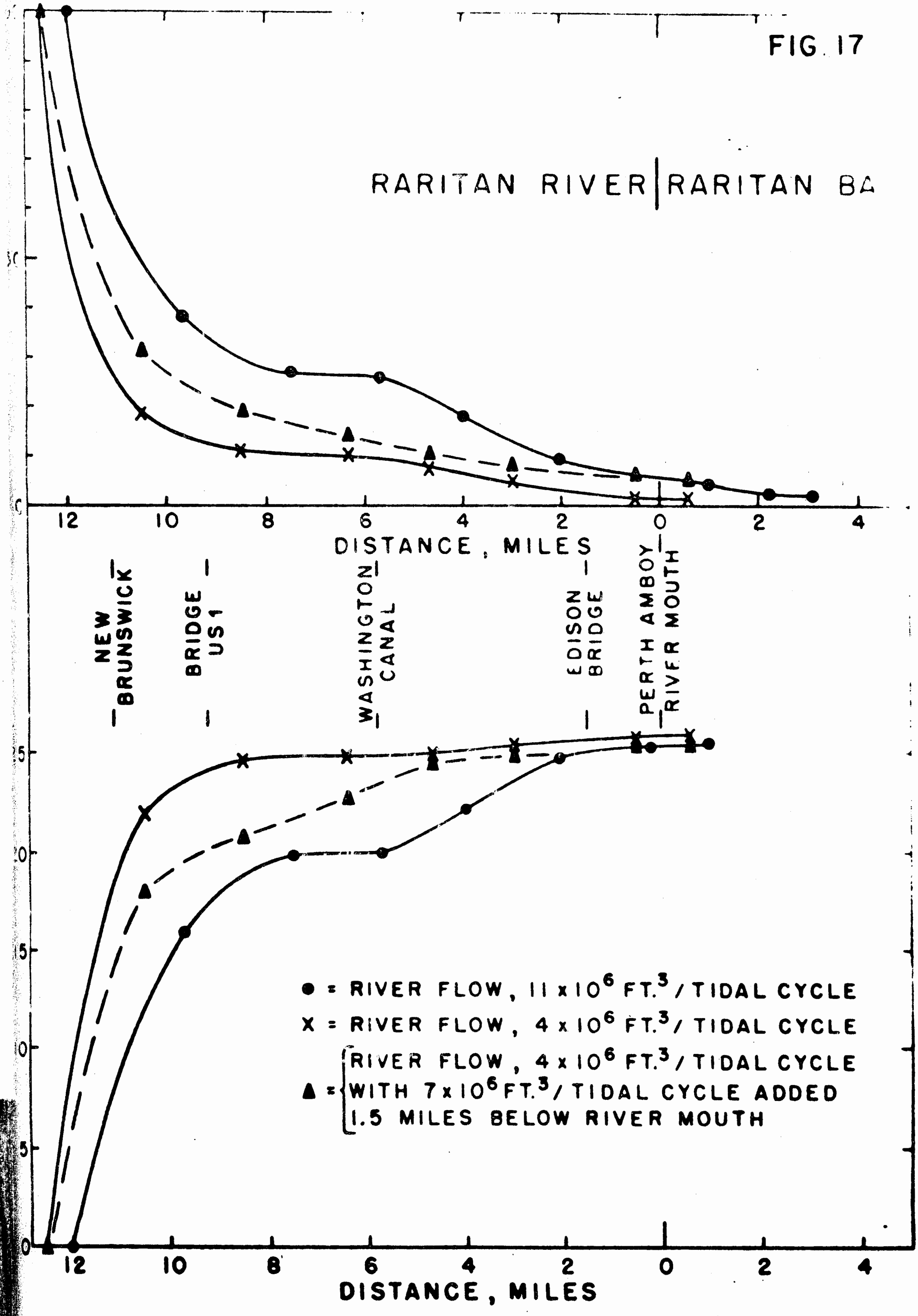
3. The distribution of salinity predicted if the effluent is reintroduced into the circulation at a location 1-1/2 miles off South Amboy.

It will be obvious that the second condition would be expected if the trunk sewer conducted the effluent well out to sea. The effect of reintroducing the effluent close to the river mouth results in the tidal oscillations returning some of the fresh water up the river and naturally produces a decrease in the espected salinity of the river.

The results of these calculations are shown in figure 17 which presents the average percentage of Raritan River water and the average salinity expected at various locations within the Raritan River. At the mouth of the river there is very little difference in salinity as a result of diverting some of the river water in a trunk sewer. At this point the minimum river flow may be expected to produce a salinity of 25.6 o/oo; complete removal of 100 million gallons per day would produce a salinity of 26.5 o/oo; reintroduction of the effluent into the Bay a mile and a half from South Amboy would produce a salinity of 25.3 o/oo. At the mouth of the Washington canal (6 miles from river mouth) the corresponding salinities would be 20 o/oo for minimum river flow; 24.5 o/oo for the complete removal of effluent; and 23.6 o/oo for the reintroduced effluent.

It should be emphasized that the salinities quoted above, and shown in the Figure, are for the high tide condition which

FIG. 17



RARITAN RIVER | RARITAN BA
12 10 8 6 4 2 0 2 4
DISTANCE, MILES
NEW BRUNSWICK
BRIDGE US1
WASHINGTON CANAL
EDISON BRIDGE
PERTH AMBOY RIVER MOUTH
25
20
15
10
5
0
● = RIVER FLOW, 11 x 10^6 FT.^3 / TIDAL CYCLE
X = RIVER FLOW, 4 x 10^6 FT.^3 / TIDAL CYCLE
▲ = RIVER FLOW, 4 x 10^6 FT.^3 / TIDAL CYCLE WITH 7 x 10^6 FT.^3 / TIDAL CYCLE ADDED 1.5 MILES BELOW RIVER MOUTH
12 10 8 6 4 2 0 2 4
DISTANCE, MILES

would produce, at any given location, maximum salinities during the tidal cycle. Since the calculations were made for minimum river flow they are also maximum salinities to be expected during the year. It may be well to point out, however, that, for short periods of time, flows even smaller than the minimum mean monthly flow may be observed. If such reduced flows were to persist for a week or more, a corresponding increase of salinity in the river may be expected. Exceptionally low flows for shorter periods of time will have little effect.

Bostwick H. Ketchum "

f. Conclusions

Calculations on the water losses from the river and increases in salinity of the tidal section of the river indicate that:

1. The reduction in river flow above the 5-mile dam may amount to about 8 percent during the lowest average daily flow for any year and to 15.4 percent for the lowest average daily flow for any month reported.

2. Removal of the effluents from the river would not affect the volume of flow in the tidal section of the river.

3. Removal of waste effluents from the river would increase the average salt concentration of the tidal section by about one percent.

4. Removal of the waste effluents from the river and reintroduction of the treated effluent in the bay may increase the salt concentration of the water at high tide in the Washington Canal by about 5 percent at the lowest average

daily flow for any month recorded.

5. The effect of diversion of waste effluents from the river and reintroduction of the treated effluent in the bay would be insignificant on the volume of the river. It is doubtful that the increase in the salinity of the water could be measured in the tidal section, including the Washington Canal.

Appendix

D. Sampling Stations, Collection of Samples and Analyses

I. Sampling Stations

Sampling stations location were chosen to show the existing conditions in the river as the result of the addition of pollution, to show the overall condition of the waters at the head end of the bay, determine the cumulative effect of the pollutional matter discharged, and estimate the probably effect upon the river and bay when all wastes were collected and treated at a central point with the effluent discharged at a given position in the bay.

For the purpose of comparing existing conditions with those of previous years an effort was made to choose sampling locations on the river and bay which would conform to sampling stations of previous surveys.

Sixteen sampling stations were located in the bay on 1500 yard squares (7/8 mile). Two stations (8 and 9) were located off the corner points because the sampling boat could not go into shallow shore water.

In order to determine the effect of the Arthur Kill on the pollution of the bay a sampling station was located approximately 1/2 mile above the mouth of the Kill.

All sampling stations have been spotted on the map of the lower Raritan River basin (Fig. 1).

II. Collection of Samples

All samples, except those river samples above New Brunswick, were taken from a 23 ft. launch furnished by the N. J. State Dept.

of Health. The following procedure was used for collecting samples on incoming and outgoing tides.

a. Incoming Tide

Samples were taken starting at the farthest point out in the bay at the time of low tide at Sandy Hook. Samples were taken from one range before moving closer to the river mouth.

b. Outgoing Tide

Sampling for outgoing tide was more complicated because the time of high tide at South River was 40 minutes behind that at Sandy Hook and New Brunswick was 60 minutes behind. Since it was impossible to follow the incoming tide exactly, the procedure was to start taking outgoing tide samples at the time of high tide at South River or New Brunswick as the case happened to be and follow the tide down as rapidly as possible. This procedure usually meant that bay samples were first taken 1½ to 2 hours after high tide at Sandy Hook and that the average condition of the bay at high tide (maximum dilution) was probably slightly better than indicated by the results. The advantage of having simultaneous river and bay samples outweighed the disadvantages.

Samples were taken down river and bay samples were taken first from near the river mouth and then seaward in numerical order.

c. Sampling Procedure

Separate sets of samples were taken from the surface and bottom at each sampling station. The number of samples collected at each station for each sampling period were:

4 for 2	Bateriological determinations
2 for 1	Dissolved oxygen determinations (300 ml.)
2 for 1	B.O.D. determinations (300 ml.)
2 for 1	Chemical analysis (300 ml.)

Surface samples were taken at a depth of 6 to 12 inches, bacteriological sample bottles were scooped into the water from the end of a sampling stick while the other samples were taken simultaneously in 300 ml. glass bottles clamped to a special sampling rod. A "thief" arrangement was provided for the B.O.D. and D.O. samples so that mixing of air and water was minimized.

Bottom sampling procedure required the use of special sampling equipment. Bacteriological samples were taken with a weighted bottle holder which had a spring loaded stopper to prevent the bottle from filling until the proper depth was reached. The bottle was rapidly filled by pulling the stopper release cord. B.O.D. and D.O. samples were taken in a depth sampler similar to the one shown on page 125 of the Ninth Edition of "Standard Methods for the Examination of Water and Sewage." The sample for chemical examination was poured from the bottom of the sampler, thus reducing the sampling interval. In general bottom samples were taken 1 to 2 feet off the bottom, except when the water exceeded the maximum sampling depth of 35 ft.

d. Number of Samples

The number of samples collected at each bay station for each sampling period were:

4 for bacteriological determinations

2 for dissolved oxygen determinations (300 ml.)

2 for B.O.D. determinations (300 ml.)

2 for chemical analysis (300 ml.)

The total number of samples collected were:

Bay	1280
River	616
Total	1896

The number of bacteriological and chemical analyses made on the bay and river samples amounted to 4034.

III. Analytical Procedure

Bacteriological: Determinations for coliform bacteria were made in the N. J. State Dept. of Health Laboratories. Standard procedures for determination of coliform bacteria numbers were used. Five replicate tubes of each dilution were made and coliform confirmation was made with brilliant green bile lactose.

B.O.D.: B.O.D. determinations were made according to Standard Methods. For Raritan Bay samples no dilutions were necessary, and B.O.D. determinations were made by the difference in dissolved oxygen between the immediate sample and that incubated at 20°C. for 5 days.

Dissolved Oxygen: Samples for dissolved oxygen were treated immediately after sampling, using the azide modification. After releasing the iodine the dissolved oxygen samples were stored, protected from direct sunlight, and titrated with standard thiosulfate solution after a maximum storage period of six hours.

Iron: Total iron was determined by the standard Colormetric - Bipyridine method using an electro-photometer.

Chlorides: Chloride determinations were made by the Mohr method as outlined in Standard Methods except that the concentration of silver nitrate was increased and the sample size decreased to accommodate the high chloride concentrations.

Alkalinity and Acidity: These determinations were made according to "Standard Methods."

pH: pH was determined with an electric pH meter.

Turbidity: Turbidity measurements were made with an electrophotometer which had been standardized against a Jackson Candle Turbidimeter.

Storage: All determinations, except as previously noted, were made on the day following the sampling. Bacteriological samples were immediately placed in portable ice boxes, while all samples were refrigerated from the time they arrived in the laboratory until they were analyzed the following morning.

TABLE I

ANALYTICAL RESULTS OF INFLUENTS AND EFFLUENTS OF MUNICIPAL PLANTS

	FLOW	PH		ALKALINITY		SUSPENDED SOLIDS		DISSOLVED OXYGEN		B.O.D.		COLIFORMS		CL RESIDUAL
	MGD	INF.	EFFL.	INF. PPM	EFFL. PPM	INF. PPM	EFFL. PPM	INF. PPM	EFFL. PPM	INF PPM	EFFL. PPM	INF. MPN/ML	EFFL. MPN/ML	EFFL. PPM
BOUND BROOK	0.6 (1)	6.9	6.9	225	213	331	82	0	1.1	570	309	100,000	10,000	—
DIEHL MFG. CO.	0.05 (1)	6.5	6.3	91	64	66	3	3.6	6.0	132	6	600,000	0	1+
	0.05 (2)													
HIGHLAND PK.	0.8 (1)	6.6	6.4	152	117	274	76	0	0.1	332	123	100,000	8,400	—
JOHNS MANVILLE	0.12 (2)	7.0	6.5	74	39	26	9	4.5	6.3	42	3	270	0	0.3
RES. CENTER	0.11 (3)													
MANVILLE	0.8 (2)	7.4	6.6	243	64	218	20	0	3.4	298	13	280,000	1,350	0.04
	0.7 (3)													
METUCHEN	0.65 (1)	6.8	7.1	258	187	338	74	0	2.2	400	102	100,000	10,000	—
MIDDLESEX	1.06 (2)	5.6	5.2	104	61	157	72	0	0	822	394	10,000	280	0
	.60 (3)													
NEW BRUNSWICK	10.5 (2)	7.8	6.2	236	203	435	218	0	0	1,013	872	2,800	5.8	0.36
	9.4 (4)	—	—	—	—	502	200	—	—	570	260	—	—	—
NORTH BRUNSWICK	0.5	6.4	6.4	148	73	156	103	0.85	5.95	288	116	660,000	1.5	—
PERTH AMBOY	6.9 (2)	6.5	7.7	120	167	231	54	2.3	4.1	196	85	1,370	6.9	1.0
	6.9 (3)													
PLAINFIELD	8.3 (2)	6.6	6.7	270	180	194	22	0	2.9	446	25	6,200	57	0.1
	5.4 (3)	—	—	—	—	280	62	—	—	205	20	—	—	—
RARITAN	1.1 (1)	7.0	5.3	160	46	317	49	1.4	4.0	514	206	—	—	—
RARITAN TWP.	0.27 (2)	7.1	6.7	245	203	232	112	0	1.9	195	135	8,000	46	0.2
CLARA BARTON	0.3 (3)													
RARITAN TWP.	1.2 (2)	6.7	6.8	202	187	174	78	0	4.4	227	126	400,000	4,600	—
PISCATAWAY	1.2 (3)													
RUTGERS	0.13 (2)	6.6	6.7	102	42	102	10	2.0	4.8	112	10	840,000	0.4	0.3
SAYREVILLE	0.6 (1)	6.8	7.1	189	158	241	43	1.3	4.4	268	42	400,000	0	—
SAYREVILLE;	.01 (2)	6.4	5.8	141	56	263	80	6.8	8.4	256	47	800	0	2.0
MELROSE SEC.	.01 (3)													
SOMERVILLE	1.3 (3)	6.7	6.4	179	110	196	18	0.7	3.1	302	155	96,000	1.5	—
SO. AMBOY	0.74 (2)	6.5	6.6	218	150	283	117	0.2	0.5	413	205	1,000,000	0.8	0.8
	0.65													
SO. BOUND BROOK	0.2	6.9	7.0	228	231	122	56	0.1	2.0	346	176	960,000	1,600	0
SO. RIVER	1.4 (2)	6.8	6.2	176	113	269	112	0	0.5	255	122	8,200	17	0.5
	1.1 (3)													
WOODBRIDGE TWP.	.54 (2)	7.1	6.9	301	214	320	93	0	3.4	267	112	560,000	8.5	—
	0.8 (3)													

(1) DAILY AVERAGE FLOW; (2) FLOW DURING TEST PERIOD; (3) FLOW DURING ONE WEEK; (4) ON THE BASIS OF 6 MONTHS AVERAGES

TABLE J

ANALYTICAL RESULTS OF INFLUENTS AND EFFLUENTS OF INDUSTRIAL PLANTS

	FLOW	PH		ALKALINITY		SUSPENDED SOLIDS		DISSOLVED OXYGEN		B.O.D.		COLIFORMS	
	MGD	RAW	EFFL.	RAW PPM	EFFL. PPM	RAW PPM	EFFL. PPM	RAW PPM	EFFL. PPM	RAW PPM	EFFL. PPM	RAW MPN/ML.	EFFL. MPN/ML.
AMER. AGR. & CHEM. CO.	0.2	6.9	6.8	185	118	333	217	0	0	11	6.7	21	28
ANHEUSER BUSCH	0.8	6.0	—	375	—	195	—	1.0	—	1600	—	960,000	—
BAKELITE	.1(2) .08 (1)	5.0	—	40	—	1200	—	0.3	—	6236	—	0	—
BENZOL PROD.	0.07(3)	1.8	—	0	—	2.8	—	0.7	—	1082	—	0	—
CALCO	20.5 (1)	2.6	5.1	0	41	179	9.6	0.25	0	238	209	0	.2
DREYFUS	.03(2) - .04(1)	7.6	6.1	1067	194	547	114	0	4.3	2440	33	—	0
DUPONT PHOTO PROD.	1.47(1)	5.1	—	36	—	12	—	1.1	—	230	—	0.7	—
DUPONT F. & F. PLANT	1.32(1)	5.9	—	31	—	17.6	—	5.6	—	52	—	2.4	—
FORD	.017	9.4	—	305	—	192	—	0	—	156	—	0	00
HERCULES	5.04 (2)	1.3	9.1	0	310	76	395	1.9	2.3	100	67	0	0
HEYDEN	0.3	8.5	7.1	417	600	151	1340	1.8	3.4	1783	2265	—	4400
JOHNS MANVILLE	3.2 (2) - 2.3 (1)	9.9	7.7	178	83	630	32	6.5	5.9	31	59	—	1100
NATIONAL LEAD	30 (3)	2.9	—	—	—	34	—	1.3	—	5.6	—	0	—
RUBEROID	0.1	12.1	12.0	1930	1550	546	55	6.3	6.6	4.6	15	0	0
SCHWEITZER	2.08(1)	9.5	—	1440	—	548	—	0	—	721	—	0	—
SHERWIN WILLIAMS	0.05	2.7	—	0	—	38	—	6.6	—	9	—	0	—

(1) DURING TEST PERIOD

(2) DURING PRECEEDING WEEK

(3) ESTIMATED

TABLE K

Special Analyses of Certain Industrial Wastes

	Bakelite	Ford	Sherwin Williams	Dupont Photo Prod.	Dupont F.&F.	Schweitzer
Phenols, ppm	1087					
Formaldehyde, ppm	1960					
Total Solids, ppm		726				
Total N, ppm		3				
Phosphates, ppm		28				
Chromium, ppm		0				
Lead, ppm			0			
Copper, ppm			5.8			
Arsenic, ppm			375			
Color, ppm				25	80	
Turbidity, ppm				10	21	730

TABLE L

Oxygen Consumed Values of Industrial Wastes

	Raw ppm	Effluent ppm
American Agr. Chem. Co.	67	66
Anheuser Busch	1,229	--
Bakelite	6,850	--
Benzol Prod.	327	--
Calco	299	190
Dreyfus	1,725	145
Dupont Photo Prod.	27	--
Dupont F. & F.	10	--
Ford	80	--
Hercules	66	61
Heyden	444	1,118
Johns Manville	11	32
National Lead	37	--
Ruberoid	5	4
Schweitzer	1,986	--
Sherwin Williams	17	--

TABLE A
RARITAN BAY SURVEY
JULY 24, 1950
TABLE A

INCOMING TIDE — LOW TIDE AT SANDY HOOK 10:02 A.M.

RUN 1

STATION NUMBER		DEPTH-FT. ACTUAL	DEPTH-FT. SAMPLE	SAMPLE TIME	TIME AFTER LOW TIDE	TEMP. °C.	D. O. PPM	D. O. % SAT.	PH	ACID ALK. PPM $CACO_3$		TURB. PPM	TOTAL FE. PPM	CHLORIDES PPM	MPN PER ML.
1	T														>1600
	M	20	6	2:10	4:08	26	1.8	24	7.1	10	76	42	1.6	6,600	
	B														>1600
2	T					25.5	1.2	15	7.0	12	72	36	1.1	4,600	>1600
	B	31	24			25	1.1	14	7.0	16	74	45	1.5	5,300	>1600
3	T			1:20	3:18	25	3.9	51	7.2	16	76	28	1.1	8,300	>1260
	B	20+	15			25	3.4	45	7.3	20	84	48	2.2	10,800	350
4	T					25	4.9	64	7.4	22	88	29	0.9	10,300	144
	B	30+	30			24	4.4	58	7.4	24	90	28	0.8	11,700	90
5	T			11:15	1:13	24	5.0	66	7.6	20	108	25	0.4	12,400	1.5
	B	30	30			23.8	4.5	60	7.5	24	108	17	0.2	13,300	2.8
6	T					24.5	5.2	69	7.6	22	92	20	0.6	11,900	39
	B	13	12				4.7	62	7.6	20	100	18	0.9	12,400	84
7	T					24	5.2	70	7.7	16	100	29	1.0	13,400	4.1
	B	4	3				5.2	69	7.7	24	104	36	2.3	13,000	18.5
8	T					23	5.8	76	7.7	16	98	19	0.3	13,300	7.6
	B														2.8
9	T					24	5.8	76	7.7	20	96	22	0.4	11,700	4.1
	B														4.1
10	T														4.1
	B	8	7			23.5	5.3	71	7.8	22	98	24	0.5	13,900	6.4
11	T														5.0
	B	9	7			23.5	5.0	67	7.8	22	100	98	4.7	13,800	13.0
12	T			11:35	1:33	24	5.0	67	7.9	18	104	21	0.3	13,100	.85
	B	30+	30			23.6	4.5	60	7.8	18	102	17	0.3	13,900	.41
13	T			11:05	1:03	23.6	5.9	80	7.9	18	104	19	0.3	14,200	.33
	B	7	5			23	5.9	78	8.0	22	104	15	0.3	14,300	.41
14	T					23.8	5.3	72	7.8	14	100	16	0.3	13,800	.36
	B	12	12			23	4.5	60	7.8	20	100	226	11.4	14,500	.80
15	T					24	5.1	69	7.6	16	96	16	0.3	14,100	1.55
	B	9	7				4.9	66	7.7	20	98	16	0.5	14,400	1.80
16	T					24	5.1	69	6.5	22	92	18	0.4	13,600	2.80
	B	8.5	7			23	4.5	60	6.2	20	96	17	0.3	13,600	1.75
17	T			10:30	0:28	24	5.3	71	7.9	20	94	15	0.3	14,000	.33
	B	9	8			23	4.8	64	7.9	18	100	14	0.2	13,700	1.70
18	T					24	5.3	71	7.9	18	98	16	0.3	13,900	1.76
	B	12	10			23	4.9	65	5.9	56	24	13	0.5	14,300	.27
19	T					24	5.7	77	8.0	16	96	13	2.8	13,700	.19
	B	14	12				5.3	71	8.0	18	96	14	0.3	13,800	2.61
20	T			10:00	0:00		6.1	82	8.1	14	96	13	0.2	14,000	.04
	B	14	10				5.6	75	7.7	20	96	13	0.4	14,000	.25

T - TOP SAMPLE
B - BOTTOM SAMPLE
M - HALFWAY SAMPLE

TABLE F
RARITAN BAY SURVEY
AUGUST 9, 1950
TABLE F
RUN VI

INCOMING TIDE

LOW TIDE AT SANDY HOOK 11:09 A.M.

SAMPLE NO.		DEPTH ACTUAL	DEPTH SAMPLE	SAMPLE TIME	TIME AFTER LOW TIDE	TEMP. $^{0}C.$	D.O. PPM	D.O. % SAT.	PH	ACID PPM	ALK. $CACO_3$	TURB. PPM.	TOTAL FE. PPM	CHLORIDES PPM	BOD PPM	MPN PER ML.
1	T	--	13	2:16	3:07	23	1.1	13	7.3	13	78	21	1.2	6,500	4.4	15,000
	B					22.8	0.6	8	7.3	21	96	19	1.3	10,700	3.4	6,400
2	T	27	20	2:07	2:58	24.0	0.5	6	7.5	14	52	28	1.0	2,700	7.4	30,000
	B					23.0	1.0	12	7.2	16	80	24	1.1	7,800	4.4	24,000
3	T	27	20	1:47	2:38	23.2	1.8	22	7.5	12	74	18	0.9	7,200	4.2	3,600
	B					22.8	2.5	31	7.4	18	76	23	1.0	8,700	3.8	4,100
4	T	30+	30	1:30	2:21	23.0	3.5	44	7.5	16	80	16	0.9	8,700	3.2	490
	B					22.5	4.1	55	7.4	20	96	14	0.6	13,700	1.8	230
5	T	30+	30	12:21	1:12	24.0	4.8	65	7.8	25	106	15	0.3	14,000	2.1	4.6
	B					22.0	3.9	52	7.8	22	104	15	0.3	13,000	1.6	2.0
6	T	24	14	1:19	2:10	23.5	4.4	59	8.0	19	94	20	0.9	12,100	1.9	109
	B					23.0	3.8	51	8.0	21	104	18	0.8	14,300	1.5	89
7	T	8	6	1:09	2:00	23.5	5.6	74	8.0	16	96	18	0.6	12,100	2.7	445
	B					23.0	5.3	71	8.0	24	100	14	0.5	14,500	2.4	380
8	T	7	4	1:02	1:53	22.8	6.9	92	8.1	15	98	14	0.3	14,000	3.6	5.9
	B					22.7	7.3	97	8.1	13	104	12	0.3	14,400	4.7	25.6
9	T	9	7	12:54	1:45	23.0	7.0	95	7.9	18	102	18	0.3	14,600	3.3	28.0
	B					22.0	5.7	75	8.0	19	108	12	0.4	14,800	2.2	18.0
10	T	9	7	12:48	1:39	23.0	5.2	69	7.8	18	96	16	0.7	13,600	3.0	445
	B					22.0	4.9	64	7.8	22	112	13	0.5	14,700	2.1	525
11	T	10	8	12:42	1:33	23.0	4.8	64	7.8	20	104	15	0.5	14,300	1.8	240
	B					22.0	4.4	57	7.8	19	106	19	0.4	14,500	1.5	41
12	T	30+	30	12:31	1:22	22.5	3.9	53	7.5	22	110	10	0.3	14,700	1.2	3.6
	B					23.0	3.9	53	7.7	20	106	14	0.3	14,700	1.4	4.1
13	T	6	5	12:03	0:52	22.7	5.4	73	7.7	17	106	12	0.2	14,900	2.2	6.4
	B					21.4	5.2	69	7.9	15	106	9	0.2	15,300	1.9	14.4
14	T	17	10	11:54	0:43	23.0	5.0	66	7.9	15	102	15	0.6	13,500	1.4	13.6
	B					22.0	4.3	57	7.9	18	110	16	0.4	15,000	1.4	107
15	T	10	8	11:49	0:40	23.0	5.4	72	7.7	20	104	14	0.5	13,000	1.9	<107
	B					22.0	4.4	58	7.9	14	104	13	0.5	14,600	2.2	160
16	T	10	8	11:39	0:30	22.8	5.3	72	8.0	24	100	12	0.5	14,900	1.8	>160
	B					22.0	4.5	59	8.0	21	110	12	0.4	15,100	2.4	26
17	T	11	9	11:30	0:21	22.8	5.8	79	7.9	17	108	14	0.4	15,800	2.0	>160
	B					22.0	4.5	58	8.0	18	106	12	0.5	14,200	1.9	39
18	T	11	8	11:21	0:12	22.0	5.3	70	8.0	16	110	14	0.4	14,900	3.1	39
	B					21.7	4.6	60	8.0	21	108	13	0.5	14,700	2.3	35
19	T	14	12	11:14	0:05	22.0	5.8	77	7.9	20	104	14	0.3	16,000	1.6	24
	B					21.7	3.4	45	7.9	17	110	12	0.5	15,400	0.7	29.4
20	T	15	13	11:04	0:05	22.0	5.5	72	7.9	11	108	11	0.3	15,500	2.2	29.5
	B					21.5	4.4	58	7.9	14	108	12	0.4	14,800	1.9	15.9

TABLE B

RARITAN BAY SURVEY

JULY 26, 1950

TABLE B

RUN 11

INCOMING TIDE

LOW TIDE AT SANDY HOOK 12:04 P.M.

STATION NUMBER		DEPTH-FT. ACTUAL	DEPTH-FT. SAMPLE	SAMPLE TIME	TIME AFTER LOW TIDE	TEMP. °C.	D.O. PPM	D.O. % SAT.	PH	ACID PPM	ALK. $CACO_3$	TURB. PPM	TOTAL FE PPM	CHLORIDES PPM	MPN PER ML.
1	T	20	18	3:18	3:14	23.9	0.5	6	7.0	12	76	41	1.8	4,000	>1600
	B					23	0.3	3	7.0	11	76	52	2.8	4,200	>1600
2	T	31	25	3:07	3:03	24	0.6	7	7.0	10	76	41	2.2	3,400	>1600
	B					23.7	0.2	2	7.0	11	72	45	1.9	3,600	>1600
3	T	20	15	2:48	2:44	24	2.6	33	7.0	13	74	48	2.4	7,100	>1600
	B					23.3	2.1	26	7.2	11	88	30.5	1.5	9,200	635
4	T	30 +	30	2:31	2:27	23.2	4.0	52	7.4	11	96	25	1.6	11,000	880
	B					22	3.9	50	7.6	12	98	45	2.7	13,000	160
5	T	30 +	30	1:18	1:14	23.6	4.4	59	7.7	10	96	26.5	0.3	12,500	29.5
	B					22.5	3.7	48	7.7	9	102	20	0.2	13,800	58.0
6	T	13	12	2:21	2:17	23.2	4.9	64	7.7	10	98	23	0.6	12,600	126
	B					22.8	3.6	47	7.6	10	102	27.5	0.9	13,100	39
7	T	4	3	2:09	2:05	22.9	5.1	67	7.5	10	98	22	0.8	12,200	126
	B					22.3	5.2	66	7.6	10	96	25	0.7	12,200	73
8	T	4	3	2:00	1:56	22.8	6.1	81	7.8	9	106	19	0.5	14,000	16
	B					22.2	6.0	77	7.7	9	104	22	0.3	13,400	31
9	T	8	5	1:53	1:49	22.7	5.5	72	7.8	8	106	20	0.5	12,900	107
	B					22	5.6	72	7.8	6	106	21	0.4	13,000	88
10	T	8	7	1:46	1:42	23	4.9	65	7.6	8	116	22	1.5	14,000	>160
	B					22.6	4.6	60	7.6	8	100	27	0.8	12,900	>160
11	T	9	7	1:39	1:35	23	5.1	67	7.7	7	98	21	0.5	12,600	126
	B					22.2	4.5	57	7.8	8	110	21	0.4	12,500	63
12	T	30 +	30	1:26	1:22	23.4	4.5	60	7.8	7	108	25	0.3	13,300	8
	B					22	3.8	49.5	7.8	9	112	22	0.3	13,600	3.6
13	T	7	5	1:04	1:00	22.1	5.1	67	7.9	7	110	16	0.2	14,900	5.1
	B					21.6	4.9	64	7.9	7	108	19	0.2	14,500	6.7
14	T	12	10	12:53	0:49	22.8	4.5	60	7.8	6	114	19	0.2	14,200	100
	B					22.3	4.3	56	7.8	8	106	19	0.4	13,700	11
15	T	9	7	12:46	0:42	23	4.6	60	7.6	9	100	20	1.1	13,200	45
	B					22.7	4.5	59	7.7	7	106	27	1.0	13,100	126
16	T	8.5	7	12:40	0:36	22.3	5.2	66	7.8	7	106	20	0.5	13,600	63
	B					22	5.0	65	7.8	7	100	21	0.5	13,500	39
17	T	9	8	12:30	0:24	23	5.3	71	7.8	6	110	20	0.4	13,500	29
	B					21.5	5.2	68	7.9	9	100	22	0.5	14,500	16
18	T	12	10	12:20	0:16	22.6	5.1	68	7.9	5	114	20	0.4	14,300	24
	B					22.3	4.9	63	7.8	5	114	21	0.3	14,000	97
19	T	14	12	12:10	0:06	23.2	4.8	66	7.9	7	114	18	0.2	15,100	15
	B					22	4.1	54	7.9	7	116	19	0.4	14,800	32
20	T	14	10	12:00	0:00	22	5.2	68	7.9	6	104	15	0.2	14,800	4.6
	B					22	4.7	61	7.9	7	114	16	0.2	15,500	1.0

T - TOP SAMPLE
B - BOTTOM SAMPLE

TABLE C
RARITAN BAY SURVEY
JULY 31, 1950
TABLE C
RUN III

OUTGOING TIDE

HIGH TIDE AT SANDY HOOK 10:12 A.M.

STATION NUMBER		DEPTH-FT. ACTUAL	DEPTH-FT. SAMPLE	SAMPLE TIME	TIME AFTER HIGH TIDE	TEMP. °C.	D.O. PPM	D.O. % SAT.	pH	ACID PPM	ALK. $CACO_3$	TURB. PPM	TOTAL FE PPM	CHLORIDES PPM	BOD PPM	MPN PER ML.
1	T			12:03	1:51	26.5	1.8	23	7.0	23	110	46	1.3	4,900	7.9	20,000
	B	21	20			26.0	0.7	9	7.2	15	110	37	1.4	9,200	4.9	14,400
2	T			12:12	2:00	26.0	1.6	21	7.2	14	104	20	0.7	8,800	4.2	5,600
	B	24.5	24			25.5	0.6	8	7.2	14	112	31	1.1	9,200	4.1	2,300
3	T			12:30	2:18	25.7	3.8	51	-	-	-	-	-	-	4.7	1,260
	B	23	18			24.7	3.2	43	7.3	27	112	29	1.0	12,800	3.1	1,600
4	T			12:42	2:30	25.7	4.3	60	7.6	15	112	30	2.3	13,000	4.1	920
	B	33	30			24.5	3.8	52	7.6	15	120	23	2.0	14,500	3.1	260
5	T			1:21	3:09	24.7	5.6	78	7.9	11	122	19	0.2	14,800	3.6	>18.5
	B	40 +	33			23.0	4.7	64	7.9	12	124	18	0.4	15,100	3.4	>16.6
6	T			1:12	3:00	25.0	4.8	67	7.6	18	128	21	0.9	13,900	2.7	>166.0
	B	20	14			24.0	4.3	58	7.8	15	130	26	0.7	14,500	1.7	>166.0
7	T			1:05	3:53	25.0	4.9	68	7.8	16	118	13	0.2	14,100	1.3	>166.0
	B	9	4			24.0	4.7	64	7.9	18	132	16	0.5	14,200	1.4	24.0
8	T			12:56	2:44	25.0	-	-	8.0	14	128	11	0.3	14,000	-	19.5
	B	5	4			24.0	6.3	85	7.9	15	138	18	0.3	14,300	2.8	86.5
9	T			1:56	3:44	25.1	6.7	92	7.9	10	116	17	0.3	13,900	3.6	35.5
	B	9.5	8.5			24.0	5.1	70	7.9	12	114	15	0.4	14,700	2.0	35.0
10	T			1:49	3:37	25.6	5.8	82	7.9	13	124	14	0.3	14,600	2.4	35.0
	B	10	9			24.2	4.8	66	7.9	11	118	18	0.3	15,500	1.6	35.0
11	T			1:41	3:29	24.8	5.0	71	7.8	14	118	14	0.4	15,000	2.6	>24.0
	B	11	10			24.0	4.8	66	8.0	14	116	16	0.3	15,500	1.8	>24.0
12	T			1:30	3:18	24.8	6.7	94	8.0	15	120	14	0.1	15,500	4.1	>24.0
	B	40	32			24.0	5.0	69	8.0	14	126	19	0.2	16,400	1.5	>24.0
13	T			2:31	4:19	24.8	7.0	99	8.1	12	124	21	0.2	14,700	2.9	>24.0
	B	5.5	4.5			24.1	6.7	92	8.1	12	130	22	0.2	15,400	2.0	>24.0
14	T			2:20	4:08	24.1	5.6	77	8.6	8	122	14	0.2	14,700	2.8	>24.0
	B	17	12			23.7	5.3	72	8.1	7	130	17	0.2	14,300	2.0	16.6
15	T			2:11	3:59	25.0	5.5	78	7.9	11	118	14	0.2	14,700	2.3	>24.0
	B	10.5	9			24.0	4.8	65	7.9	9	120	15	0.3	14,400	1.8	>24.0
16	T			2:00	3:48	25.1	6.0	84	8.0	10	114	18	0.3	14,200	3.1	>24.0
	B	7	6			24.5	6.1	86	8.0	9	116	17	0.3	16,200	2.8	>24.0
17	T			3:00	4:48	25.0	7.5	105	8.1	19	116	23	0.3	14,700	4.3	9.2
	B	10.5	9			24.0	5.5	77	8.0	13	122	26	0.4	15,900	2.1	>24.0
18	T			2:55	4:43	24.2	6.1	84	8.0	9	110	16	0.2	15,300	2.8	>20.0
	B	12	10			23.2	5.2	71	8.0	12	114	16	0.3	15,000	1.9	>24.0
19	T			2:47	4:35	23.8	6.0	83	8.1	10	116	14	0.1	15,800	2.9	>24.0
	B	15	14			22.9	4.9	67	7.9	12	116	14	0.2	16,000	1.6	6.3
20	T			2:39	4:27	24.2	6.7	93	8.1	9	114	12	0.1	15,200	3.4	13.3
	B	18	15			23.0	5.5	75	8.2	11	116	16	0.2	16,000	2.0	6.3

T - TOP SAMPLES
B - BOTTOM SAMPLE

TABLE D
RARITAN BAY SURVEY
AUGUST 2, 1950
TABLE D
RUN IV

OUTGOING TIDE

HIGH TIDE AT SANDY HOOK 11:42 A.M.

STATION NUMBER		DEPTH FT. ACTUAL	DEPTH FT. SAMPLE	SAMPLE TIME	TIME AFTER HIGH TIDE	TEMP. °C.	D.O. PPM	D.O. % SAT.	PH	ACID PPM	ALK. $CACO_3$	TURB. PPM	TOTAL FE.	CHLORIDE PPM	BOD PPM	MPN PER ML.
A	T	18	15	12:42	1:00	25.5	0	0	6.9	18	78	60	1.8	600	31	>100,000
	B					24.5	0	0	6.8	18	80	74	2.0	750	36	>100,000
B	T	20	15	12:56	1:14	25.0	0	0	6.9	19	90	62	2.1	1,250	32	>100,000
	B					24.0	0	0	7.0	18	96	80	2.0	1,900	24	>100,000
1	T	23	18	1:31	1:49	24.0	0.6	7	7.0	22	102	39	1.2	4,700	6.6	90
	B					23.8	0.8	10	7.2	16	106	32	1.0	8,400	4.2	1,310
2	T	28	23	1:19	1:27	24.1	1.0	13	7.2	16	112	25	0.6	8,700	3.7	505
	B					23.8	0.8	10	7.3	15	102	28	1.0	9,200	4.6	138
3	T	26	18	1:57	2:19	23.7	3.5	46	7.4	17	102	21	0.7	12,100	3.1	330
	B					23.0	3.2	43	7.4	12	106	28	0.9	12,800	4.0	250
4	T	33	30	2:10	2:38	23.2	3.9	53	7.6	13	106	26	0.9	13,700	3.7	1,015
	B					22.8	3.6	48	7.6	12	106	30	1.0	14,100	3.7	360
5	T	-	35	2:55	3:13	23.0	4.6	62	7.8	12	116	18	0.3	14,900	2.0	33.5
	B					22.2	4.1	56	7.9	11	114	19	0.4	15,200	2.0	7.9
6	T	26	18	2:21	2:39	23.0	4.1	56	7.7	15	112	21	0.5	14,600	1.2	54.0
	B					23.0	4.4	60	7.8	9	108	25	0.7	14,700	7.0	39.0
7	T	10	8	2:42	3:00	23.0	4.6	62	7.9	12	110	22	0.4	15,300	1.1	73.0
	B					22.8	5.5	80	8.0	8	110	27	0.5	15,800	2.5	33.5
8	T	5.5	5	2:33	2:51	23.0	6.3	85	8.0	9	118	28	0.5	15,400	4.1	2.4
	B					22.2	6.3	83	8.0	8	120	28	0.5	15,100	3.2	5.1
9	T	10	9	3:28	3:46	23.0	7.0	95	8.1	8	120	25	0.2	14,800	3.0	13.1
	B					22.5	6.7	89	8.1	8	116	27	0.4	15,100	2.8	3.6
10	T	10	10	3:21	3:39	23.0	6.4	87	8.0	8	124	23	0.4	15,100	2.2	5.6
	B					22.8	5.4	72	8.0	6	110	22	0.5	13,700	1.9	5.1
11	T	11	10	3:15	3:33	23.0	4.8	65	7.8	7	112	22	0.3	14,800	1.3	23.0
	B					22.5	4.3	57	7.9	9	126	18	0.4	15,300	1.4	16.0
12	T	-	35	3:07	5:25	23.0	4.9	66	7.8	10	122	20	0.2	15,400	1.5	24.0
	B					22.5	4.6	62	7.9	10	120	20	0.3	15,200	1.5	12.0
13	T	6.5	5	3:56	4:14	23.0	4.9	66	7.9	11	120	16	0.2	15,400	1.1	3.6
	B					22.5	4.7	64	7.9	9	118	29	0.3	15,500	1.5	14.4
14	T	20	15	3:46	4:04	23.0	6.2	84	7.9	10	114	28	0.3	15,400	2.9	7.9
	B					22.3	4.7	63	7.9	10	122	19	0.3	15,000	1.7	5.6
15	T	11	9	3:41	3:59	23.0	6.5	88	8.0	8	108	23	0.4	14,800	2.4	4.9
	B					22.5	5.7	76	8.0	7	106	23	0.5	14,900	1.8	4.1
16	T	11	6	3:34	3:52	23.0	7.6	104	8.2	4	128	26	0.3	15,800	3.9	6.4
	B					22.7	7.2	98	8.3	0	132	32	0.4	15,400	4.0	3.3
17	T	11	9	4:31	4:49	22.8	7.6	104	8.2	2	110	24	0.2	15,600	3.1	5.1
	B					22.0	5.4	72	8.1	7	120	23	0.4	15,900	1.3	2.8
18	T	12	10	4:22	4:40	22.8	7.0	95	8.1	7	114	22	0.2	15,200	3.2	17.9
	B					22.0	5.4	71	8.1	5	120	19	0.3	14,900	1.9	13.0
19	T	16	14	4:10	4:28	23.0	5.7	78	7.9	7	122	19	0.2	15,500	2.2	44.5
	B					22.7	5.8	79	8.0	13	120	20	0.4	15,800	2.5	18.5
20	T	16	15	4:04	4:22	22.8	6.0	82	8.1	7	120	21	0.2	15,900	2.4	2.4
	B					22.0	5.2	70	8.0	9	120	21	0.4	15,900	2.2	2.9

T - TOP SAMPLE
B - BOTTOM SAMPLE

TABLE E
RARITAN BAY SURVEY
AUGUST 8, 1950
TABLE E
RUN V

INCOMING TIDE — LOW TIDE AT SANDY HOOK 10:15 A.M.

STATION NUMBER		DEPTH-FT. ACTUAL	DEPTH-FT. SAMPLE	SAMPLE TIME	TIME AFTER LOW TIDE	TEMP. °C.	D.O. PPM	D.O. % SAT.	PH	ACID PPM	ALK. $CACO_3$	TURB. PPM	TOTAL FE.	CHLORIDES PPM	BOD PPM	MPN PER ML.
A	T			1:28	3:23	22.0	0.1	1	7.1	8	36	32	0.5	40	9.6	64,000
	B	15	12			21.0	0.1	1	6.8	13	34	28	0.5	150	10.8	41,000
B	T			1:30	3:15	23.0	0.0	0	7.0	14	44	46	0.7	180	15.3	214,500
	B	-	15			22.5	0.0	0	6.8	14	48	43	0.9	1,600	8.1	130,000
1	T			12:52	2:37	22.0	0.3	4	7.2	13	66	27	0.8	4,200	4.8	4,100
	B	20	17			23.0	0.8	11	7.2	19	88	24	0.8	7,400	3.4	8,900
2	T			1:01	2:46	22.8	0.3	4	7.4	13	52	32	1.0	2,300	5.8	29,500
	B	30	25			22.8	0.5	6	7.2	19	72	22	0.7	6,500	3.2	24,000
3	T			12:35	2:20	23.0	0.7	8	7.5	14	68	23	0.7	4,500	3.4	4,100
	B	25	15			22.7	1.4	18	7.4	20	94	16	0.5	11,200	1.4	815
4	T			12:21	2:06	22.9	2.3	30	7.6	18	80	16	0.4	8,000	3.4	1,545
	B	30+	30			22.0	3.4	44	7.5	19	112	21	0.8	13,600	2.0	285
5	T			11:19	1:04	22.6	4.5	60	7.4	16	118	10	0.1	14,600	1.1	10.9
	B	30+	30			21.8	3.8	50	7.5	21	118	13	0.2	14,800	1.1	10.9
6	T			12:10	1:55	22.8	4.0	52	7.3	19	102	9	0.4	11,800	1.4	350
	B	16	12			22.0	3.9	51	7.5	31	110	11	0.1	14,100	0.9	159
7	T			12:01	1:46	23.0	4.7	62	7.4	26	104	11	0.3	13,100	1.1	86
	B	8	4			21.8	5.2	67	7.5	18	106	13	0.2	13,500	3.2	81
8	T			11:55	1:40	21.8	6.3	81	7.7	24	108	15	0.1	13,000	2.5	8.9
	B	6	3			21.7	6.5	85	7.5	19	106	19	0.3	13,600	2.8	7.4
9	T			11:48	1:33	22.8	5.6	74	7.6	26	104	10	0.4	12,600	1.9	123
	B	9	5			22.7	5.7	75	7.4	22	104	15	0.3	12,800	2.4	74
10	T			11:42	1:27	22.7	4.9	65	7.3	28	112	11	0.3	13,000	1.5	175
	B	10	7			22.5	4.4	57	7.5	32	116	11	0.3	13,300	0.9	136
11	T			11:35	1:20	22.0	4.7	60	7.4	25	106	11	0.3	13,400	1.7	295
	B	10	7			22.7	4.3	57	7.5	19	114	9	0.2	14,200	1.1	74
12	T			11:16	1:11	22.7	4.5	59	7.7	20	98	12	0.3	12,800	1.5	730
	B	35+	33			22.0	4.0	53	7.7	30	116	8	0.1	15,000	1.9	41
13	T			11:04	0:49	22.0	5.1	66	7.7	23	110	10	0.1	14,500	1.3	15.5
	B	6	5			21.0	5.1	66	7.7	25	108	10	0.1	14,700	1.5	6.4
14	T			10:57	0:42	22.0	4.9	63	7.6	27	102	13	0.3	13,200	1.7	>160
	B	12	10			21.6	4.4	57	7.8	27	106	11	0.2	14,700	1.9	97
15	T			10:50	0:35	22.0	5.2	67	7.8	22	104	12	0.3	13,400	1.7	>160
	B	10	8			21.0	4.8	61	7.8	19	106	11	0.2	14,300	1.5	73
16	T			10:44	0:29	22.0	5.3	68	7.8	20	98	13	0.4	12,600	1.8	>160
	B	9	7			21.0	5.5	69	7.8	28	98	16	0.4	12,700	1.9	126
17	T			10:33	0:18	21.0	6.7	85	8.0	30	100	16	0.2	12,700	2.4	63
	B	10	7			21.0	5.4	69	7.9	20	106	14	0.3	12,900	2.0	21.4
18	T			10:22	0:07	22.0	5.5	71	7.8	17	100	11	0.4	12,900	1.4	>126
	B	10	8			21.2	4.9	64	7.9	21	114	19	0.7	14,700	1.1	>126
19	T			10:12	0:03	21.8	5.9	77	7.9	21	108	12	0.1	14,400	2.4	24
	B	15	12			21.5	5.0	66	7.9	27	108	13	0.4	15,100	1.4	15.9
20	T			10:06	0:09	22.0	5.8	75	7.6	17	100	9	0.1	13,800	2.1	7.9
	B	16	12			21.5	5.8	76	7.8	18	108	14	0.3	14,800	1.8	2.8

T - TOP SAMPLE
B - BOTTOM SAMPLE

TABLE G
RARITAN BAY SURVEY
AUGUST 14, 1950
TABLE G
RUN VII

OUTGOING TIDE

HIGH TIDE AT SANDY HOOK 9:03 A.M.

SAMPLE NO.		DEPTH ACTUAL	DEPTH SAMPLE	SAMPLE TIME	TIME AFTER HIGH TIDE	TEMP. °C.	D.O. PPM	D.O. % SAT.	PH	ACID PPM	ALK. $CaCO_3$	TURB. PPM	TOTAL FE. PPM	CHLORIDES PPM	BOD PPM	MPN PER ML.	LOG MPN
A	T	15		10:47	1:44	24	1.2	14	6.8	18	54	36	0.8	900	16	36,000	
	B		12			24	0.0	0	6.9	20	66	39	0.9	1,000	17	49,000	
B	T			10:59	1:56	23.7	0.3	3	6.9	15	64	40	1.0	1,250	17	79,000	
	B	15	14			22.7	0.0	0	7.1	16	70	40	1.1	1,650	17	28,000	
1	T			11:30	2:27	23.7	0.2	2	7.2	15	88	25	1.2	7,200	4.6	8,150	
	B	21	18			23.0	0.0	0	7.3	11	92	24	1.1	8,600	3.6	2,300	
2	T			11:22	2:19	23.7	0.4	5	7.3	11	84	21	1.0	7,700	4.2	1,545	
	B	31	23			23.0	0.2	2	7.3	10	92	23	1.0	8,700	3.0	1,500	
3	T			11:50	2:47	23.0	2.6	34	7.3	10	100	23	0.8	11,600	3.0	280	
	B	26	20			22.0	1.7	22	7.5	12	100	22	0.9	12,400	2.0	280	
4	T			12:00	2:57	22.5	4.8	64	7.6	12	106	19	0.7	14,300	1.8	4.0	
	B	35	30			22.7	4.1	55	7.8	10	110	28	1.1	14,200	2.0	64	
5	T			12:50	3:47	22.8	5.4	73	7.9	10	120	19	0.3	15,100	2.0	3.3	0.5
	B	35+	35			22.7	5.1	69	8.0	11	110	27	0.5	15,200	1.6	2.2	0.35
6	T			12:46	3:43	22.8	5.1	69	7.9	10	112	22	0.8	14,700	1.7	81.0	1.9
	B	21	19			22.8	5.1	69	7.9	11	110	24	0.9	14,700	1.8	49.0	1.7
7	T			12:32	3:29	22.7	5.7	77	8.0	11	112	11	0.3	15,000	0.9	6.4	0.8
	B	8	7			23.0	10.5	142	8.1	10	108	16	0.4	15,200	6.5	3.3	0.5
8	T			12:25	3:22	22.6	5.5	74	8.4	0	106	21	0.2	14,800	--	2.8	0.45
	B	4	3.5			23.0	10.7	145	8.3	0	98	20	0.4	15,200	5.3	1.4	0.15
9	T			1:21	4:18	23.2	9.6	131	8.7	0	106	25	0.2	15,800	2.4	0.8	—0.1
	B	10	9			22.7	7.9	106	8.3	0	106	19	0.2	15,200	1.4	0.7	—0.15
10	T			1:14	4:11	23.5	6.7	93	8.1	9	102	17	0.5	15,600	1.7	10.1	1.0
	B	10	9			23.0	6.2	85	8.0	10	104	14	0.4	15,800	1.2	9.4	1.0
11	T			1:07	4:04	23.0	5.8	78	8.0	13	106	18	0.6	15,300	2.8	70.5	1.85
	B	11	10			22.5	5.6	76	8.1	14	110	18	0.5	15,700	2.7	20.5	1.3
12	T			1:00	3:51	22.4	5.5	75	8.1	14	112	11	0.1	15,800	1.0	6.4	0.8
	B	35+	35			22.0	5.4	72	8.0	11	114	16	0.2	15,800	0.9	0.8	—0.1
13	T			1:54	4:51	22.8	7.2	97	8.1	11	106	9	0.1	14,800	1.3	0.3	—0.5
	B	6	5			22.2	7.3	97	8.1	13	110	15	0.2	15,500	1.9	2.8	0.45
14	T			1:45	4:42	23.0	6.2	85	8.1	13	100	13	0.2	15,800	5.7	1.5	0.2
	B	16	15			22.2	5.9	79	8.1	13	98	20	0.6	15,200	1.7	3.3	0.5
15	T			1:38	4:35	23.8	6.7	93	8.1	13	110	14	0.4	15,600	1.5	2.7	0.4
	B	11	9			22.2	6.8	90	8.1	10	106	19	0.2	15,400	1.8	3.5	0.55
16	T			1:26	4:23	24.0	7.9	108	8.3	0	106	17	0.4	14,900	1.9	0.5	—0.3
	B	10	6			23.0	8.1	110	8.3	0	102	13	0.3	15,100	2.2	1.0	0.0
17	T			2:28	5:25	23.8	12.8	175	8.7	0	114	30	0.2	15,200	4.5	.3	—0.5
	B	10	8			22.7	11.3	153	8.5	0	108	23	0.3	14,800	4.4	.3	—0.5
18	T			2:21	5:18	22.8	7.6	103	8.2	9	110	14	0.2	15,200	1.6	1.1	0.5
	B	11	9			22.5	7.6	101	8.3	0	110	20	0.3	15,300	1.6	2.3	0.35
19	T			2:09	5:06	23.0	6.5	89	8.1	10	110	16	0.1	16,200	0.2	1.7	0.2
	B	15	13			22.0	6.4	84	8.0	9	112	9	0.4	15,300	1.3	0.5	—0.3
20	T			2:00	4:57	22.8	7.6	103	8.1	8	106	14	0.1	15,400	2.2	.3	—0.5
	B	16	14			22.2	6.3	83	7.8	10	104	14	0.2	15,900	1.2	.3	—0.5

TABLE H
RARITAN BAY SURVEY
AUGUST 15, 1950
TABLE H

OUTGOING TIDE

HIGH TIDE AT SANDY HOOK 9:43 A.M.

RUN VIII

SAMPLE NO.		DEPTH ACTUAL	DEPTH SAMPLE	SAMPLE TIME	TIME AFTER HIGH TIDE	TEMP. °C.	D.O. PPM	D.O. % SAT.	PH	ACID PPM	ALK. $CACO_3$	TURB. PPM	TOTAL FE.	CHLORIDES PPM	BOD PPM	MPN PER ML.	LOG MPN
A	T			11:34	1:51	25	0.5	6		15	66	--	0.9	1,400	21	23,000	
	B	--	12			--	0.0	0		12	72	--	1.0	1,500	18	33,100	
B	T			11:45	2:02	25	0.5	6		13	72	--	1.0	1,750	17	36,000	
	B	--	14			--	0.0	0		11	82	--	1.1	2,750	14	28,000	
1	T			12:15	2:32	24	0.7	9		14	94	28	0.7	6,800	5.1	1,700	
	B	--	20			24	0.7	9		15	96	36	1.0	9,200	4.2	1,095	
2	T			12:07	2:24	24	0.9	12		15	88	25	0.7	9,400	4.5	284	
	B	--	25			24	0.6	8		17	98	29	1.0	9,200	5.1	640	
3	T			12:34	2:51	24	3.1	41		20	98	36	1.1	12,700	2.4	64	
	B	--	20			23	3.2	42		19	102	80	2.2	12,500	3.9	284	
4	T			1:11	3:28	23	4.4	60		18	104	22	0.5	15,600	4.0	172	
	B	--	35			22.9	5.1	70		15	104	23	0.6	16,200	3.6	102	
5	T			1:51	4:08	23	5.7	78		18	110	19	0.0	15,400	1.9	2.9	0.45
	B	--	35			22.8	5.6	76		16	106	22	0.3	15,400	2.5	0.8	—0.1
6	T			1:23	3:40	23	5.6	76		17	102	28	0.8	15,600	2.7	16.9	1.25
	B	21	18			23.0	5.3	73		14	102	33	0.9	16,000	2.7	15.0	1.2
7	T			1:39	3:56	23.0	6.4	87		16	108	25	0.6	15,600	3.3	31	1.5
	B	8	6			23.5	6.4	89		17	108	27	0.6	16,200	2.9	4.1	0.6
8	T			1:31	3:48	23.0	12.7	174		0	102	27	0.2	16,800	5.1	1.5	0.2
	B	4	3			23.3	13.1	178		3	108	25	0.1	15,600	6.2	.3	—0.5
9	T			2:21	4:38	23.0	11.8	160		0	106	26	0.1	15,600	4.5	1.3	0.1
	B	4	3			22.8	11.5	160		0	106	27	0.3	16,800	3.4	0.6	—0.2
10	T			2:14	4:31	23.0	6.4	88		13	110	16	0.1	16,400	0.8	5.1	0.7
	B	8	7			22.2	4.6	61		14	104	17	0.2	16,200	--	1.8	0.25
11	T			2:08	4:25	23.0	6.6	89		13	102	22	0.4	15,200	2.6	18.5	1.25
	B	10	8			22.8	6.1	83		16	102	26	0.5	16,000	2.0	18.5	1.25
12	T			2:00	4:17	23.0	5.8	78		16	110	16	0.1	16,000	1.5	1.5	0.2
	B	--	35			22.0	5.8	77		17	102	20	0.2	16,800	1.4	4.1	0.6
13	T			2:44	5:01	23.0	8.7	120		15	108	13	0.1	16,400	1.9	0.7	—1.15
	B	6	5			23.3	8.5	118		11	106	14	0.1	17,200	1.8	0.3	—0.5
14	T			2:37	4:54	23.0	6.8	93		13	108	14	0.1	16,000	1.5	3.3	0.5
	B	19	18			22.5	6.7	92		13	106	14	0.2	17,400	2.0	2.7	0.45
15	T			2:31	4:48	23.0	8.1	111		12	108	16	0.1	16,800	3.0	.9	—0.05
	B	8.5	7			23.0	7.0	97		13	106	17	0.2	17,400	2.0	1.3	0.1
16	T			2:26	4:43	23.0	10.1	137		0	106	33	0.2	15,400	2.0	1.3	0.1
	B	10	9			22.7	10.9	152		0	110	19	0.2	17,000	4.7	0.6	—0.2
17	T			3:13	4:30	23.0	10.6	147		0	108	25	0.3	15,600	2.0	.1	—1.0
	B	10	8			22.0	11.2	151		0	100	33	0.6	17,000	5.0	0.2	0.7
18	T			3:05	4:22	23.0	8.1	112		6	110	16	0.1	16,800	2.4	1.0	0.0
	B	12	10			22.0	7.8	103		10	112	14	0.2	16,600	3.1	.6	—0.2
19	T			2:56	4:13	23.0	8.0	110		12	114	18	0.0	16,600	2.3	1.2	1.1
	B	15	14			22.0	6.8	92		12	116	15	0.1	16,400	1.6	1.3	1.1
20	T			2:52	4:09	23.0	9.0	124		11	108	16	0.0	16,600	3.5	.8	—0.2
	B	16	15			23.0	7.9	109		9	124	16	0.0	16,400	2.6	.6	—0.4