TREATMENT REQUIREMENTS
in the
ARTHUR KILL
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1962 Annual Report
Interstate Sanitation Commission

TREATMENT REQUIREMENTS IN THE ARTHUR KILL

INTRODUCTION

The Interstate Sanitation Commission has been aware of the dissolved oxygen problem in the Arthur Kill for some time. A preliminary survey was initiated in 1955 in an effort to supplement the knowledge of the existing conditions within the waterway. Succeeding surveys were increased in scope and intensity with the express purpose of attempting to define the pollutional problems existing and how these problems might be solved by the cooperative efforts of the various municipal, industrial, state and interstate groups concerned.

It is well accepted that the condition of the Arthur Kill waters has been deteriorating over a period of years. This is due to increased development of the area, as measured by a greater residential population and industrial complex, while the size of the receiving waterway remains fixed. All of the surveys have been conducted by the Commission in recent years, and they show beyond any doubt that corrective measures must now be taken. It is our expressed desire to initiate a comprehensive pollution abatement program in the Arthur Kill that is based on sound fundamentals. It must be remembered also that this is an interstate waterway and that the equal rights of adjoining states must be honored. Certain salient information pertaining to this Commission, its activities and surveys, where considered pertinent, will be presented in the succeeding parts of this report.

JURISDICTION AND POLLUTION STANDARDS

In 1936, the Interstate Sanitation Commission was created by Compact or Treaty between New York, New Jersey and Connecticut for the abatement of existing and control of future pollution in certain interstate waters. The Tri-State Compact created an Interstate Sanitation District which embraced specific tidal waters either within or adjoining each signatory state. (See map following page 3)

The Arthur Kill is an interstate waterway separating Richmond County in New York State from Union and Middlesex Counties in the State of New Jersey. The jurisdiction of the Commission encompasses the entire thirteen mile length of the Arthur Kill. In New York (Staten Island), the Commission's jurisdiction extends inland to include any waters under tidal effect, while in New Jersey, the jurisdictional limits terminate at the mouths of the rivers entering the Arthur Kill.

The Tri-State Compact established two general water classifications, namely:

1) Class "A", in which the designated water areas are expected to be used primarily for recreational purposes, shellfish culture or the development of fish life.

2) Class "B", in which the designated water areas are not expected to be used primarily for recreational purposes, shellfish culture or the development of fish life.

Public hearings were held to determine the best usage of the Arthur Kill waters in order to classify them reasonably. It was decided to classify the Arthur Kill waters north of the Outerbridge Crossing as Class "B" waters. Concurrently, the Arthur Kill waters south of the Outerbridge Crossing were classified as "A" waters.

The Tri-State Compact set up specific standards for both domestic sewage and industrial wastes discharging into "A" or "B" waters. The partial restrictions of domestic sewage discharged or permitted to flow into Class "A" waters of the District are as follows:

(a) Removal of all floating solids and at least 60 percent of the suspended solids; and

(b) To effect a reduction in the oxygen demand of the sewage effluent sufficient to maintain an average dissolved oxygen content in the tidal waters of the District and in the general vicinity of the point of discharge of the sewage into those waters, at a depth of about five feet below the surface, of not less than 50 percent saturation during any week of the year.

The standards for sewage discharged or permitted to flow into Class "B" waters of the District are as follows:

(a) Removal of all floating solids and at least 10 percent of the suspended solids or such additional percentage as may by reason of local conditions be necessary to avoid the formation of sludge deposits in the Class "B" waters of the District; and

(b) To effect a reduction in the oxygen demand of the sewage effluent sufficient to maintain an average dissolved oxygen content in the tidal waters of the District and in the general vicinity of the point of discharge of the sewage into those waters, at a depth of about five feet below the surface, of not less than 30 percent saturation during any week of the year.

The industrial waste standards required by the Tri-State Compact for both Class "A" and Class "B" waters are as follows:

1) Removal of all floating matter such as oil, grease or solids.

2) Removal of settleable solids so as to prevent the formation of sludge deposits along the shores or in the waterways.

3) Removal of toxic materials, color or odors that would interfere with the maintenance of fish life, shellfish and marine life in waters designated Class "A" or creates a condition in District waters which is obnoxious or causes a nuisance.

4) pH - No corrections or neutralization required unless it causes a condition which violates one of the preceding standards or creates a condition which is obnoxious or causes a nuisance.

5) Reduction in oxygen demand sufficient to maintain an average dissolved oxygen content in the waters of not less than 50 percent saturation during any week of the year in Class "A" waters and 30 percent saturation during any week of the year in Class "B" waters.

WATER POLLUTION SURVEYS

Period 1950-1958

1) Southern Arthur Kill Survey - 1955

During September and October of 1955, the Commission obtained water samples by traversing via ferry a cross section in the southern end of the Kill outlined by the limits of Tottenville, Staten Island and Perth Amboy, New Jersey. The conclusions reached as a result of this survey were as follows:

a) There is a negligible amount of fresh water flow emanating from the southern end of the Arthur Kill.

b) The Kill waters are comparatively well mixed both laterally and vertically.

c) Pollution conditions became increasingly deleterious as one proceeds north into the Arthur Kill.

d) Due to lack of net flow out of the Kill, pollutional conditions of the Kill are primarily a result of pollution sources (both domestic and industrial) discharging into the Kill.

e) Further study is mandatory to include the entire Kill area.

2) Arthur Kill Pollution Survey - 1956

The second study (May through October 1956) set up a limited number of stations in the north, middle and southern sections of the Arthur Kill. A conclusion of this survey was that more than 80 percent of the biochemical oxygen demand load in the Arthur Kill originated in the area encompassing the northern limits. It was reported that half the domestic flow from the treatment plants and a majority of the heavy industries in the Arthur Kill discharge their respective wastes into this northern one third portion.

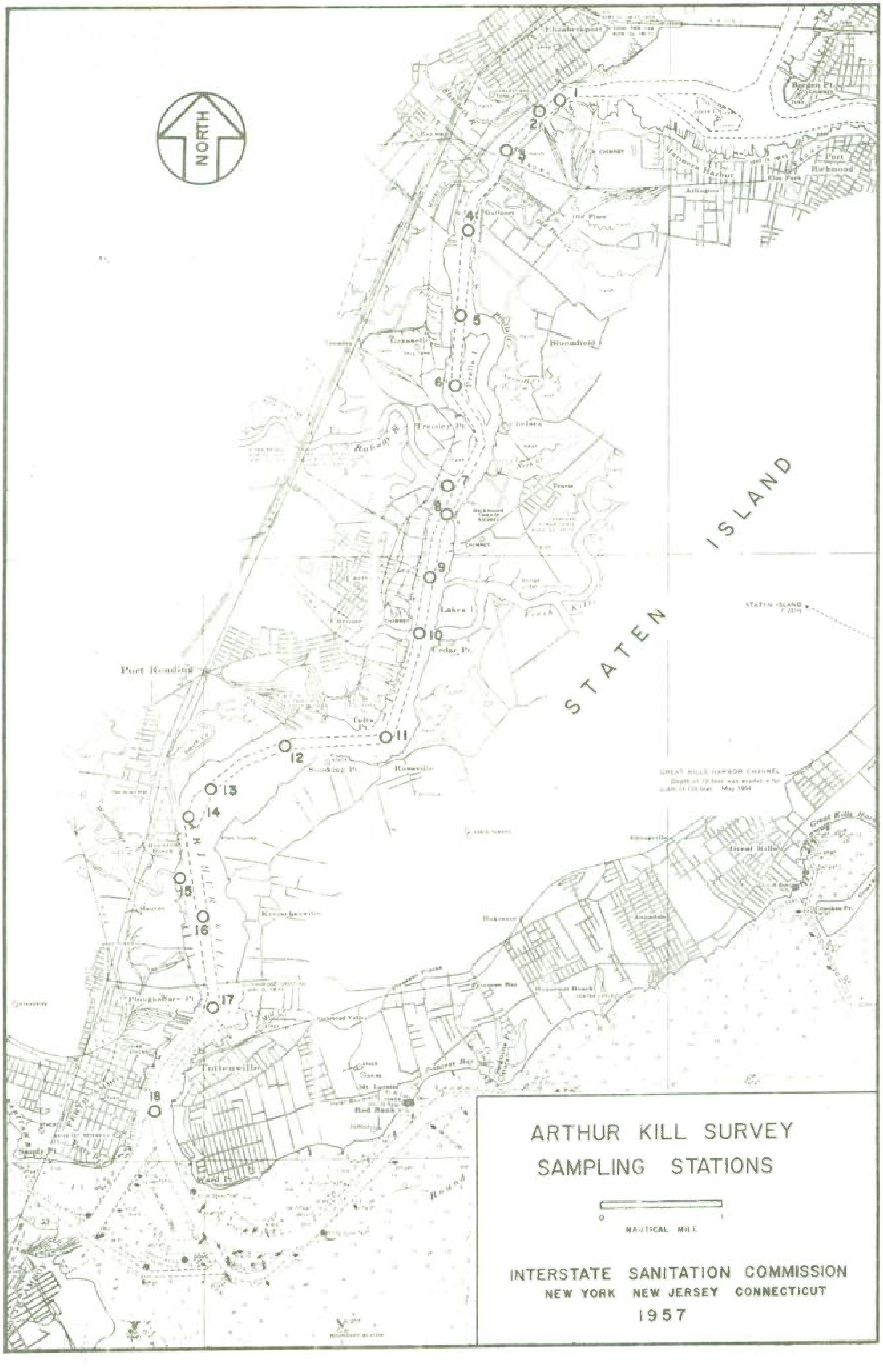
3) Arthur Kill Pollution Survey - 1957

With the 1955 and 1956 Surveys' conclusions as a foundation, the Commission in 1957 planned and conducted an intensive five week survey of these waters to determine accurately and conclusively the actual conditions existing throughout the entire length of the Arthur Kill. This survey commenced on June 17, 1957 and terminated on July 18, 1957. Eighteen carefully selected points were established and fifty samples or more were collected at each of these stations during the entire five week period. (See map on following page.) From this extensive investigation, it was established that these waters were in violation of the requirements of the Interstate Sanitation Commission Compact for approximately 60 percent of the total 13 mile length, with the point of maximum oxygen deficit occurring within an area eight miles above Raritan Bay. Plate I reflects graphically this finding with a plot of the weighted mean percent saturation of dissolved oxygen versus sampling stations (distance). Table I lists the calculated mean percent saturation of dissolved oxygen values for each station. It was also reported that there existed a "slug" of pollution in the Arthur Kill approximately 6.4 miles in length, having less than 30 percent saturation of dissolved oxygen. This slug oscillated back and forth utilizing Station 7 as the pivotal point and the tidal ebb and flood currents as the impetus. The Station 7 area was shown to be constantly under the influence of this slug of pollution. The Interstate Sanitation Commission staff devised a mathematical method for the analysis of these data.

This method, conclusions and analytical presentation of data are all recorded in the 1958 Annual Report of the Interstate Sanitation Commission.

4) Shoreline Surveys of the Arthur Kill Area

From 1936 to 1940, the Interstate Sanitation Commission prepared shoreline outfall maps of its entire District in order to pinpoint the various and numerous sources of pollution. The maps reflect the size, type and approximate location of each outlet. Immediately following the 1957 Survey, the Commission found it necessary to revise and update the outfall maps in the Arthur Kill area. This project commenced in the fall of 1957 and terminated in early 1958. One representative of the Commission was assigned the Richmond County



ARTHUR KILL SURVEY
SAMPLING STATIONS

INTERSTATE SANITATION COMMISSION
NEW YORK NEW JERSEY CONNECTICUT
1957

WEIGHTED MEAN PERCENT SATURATION OF DISSOLVED OXYGEN

1957 ARTHUR KILL SURVEY

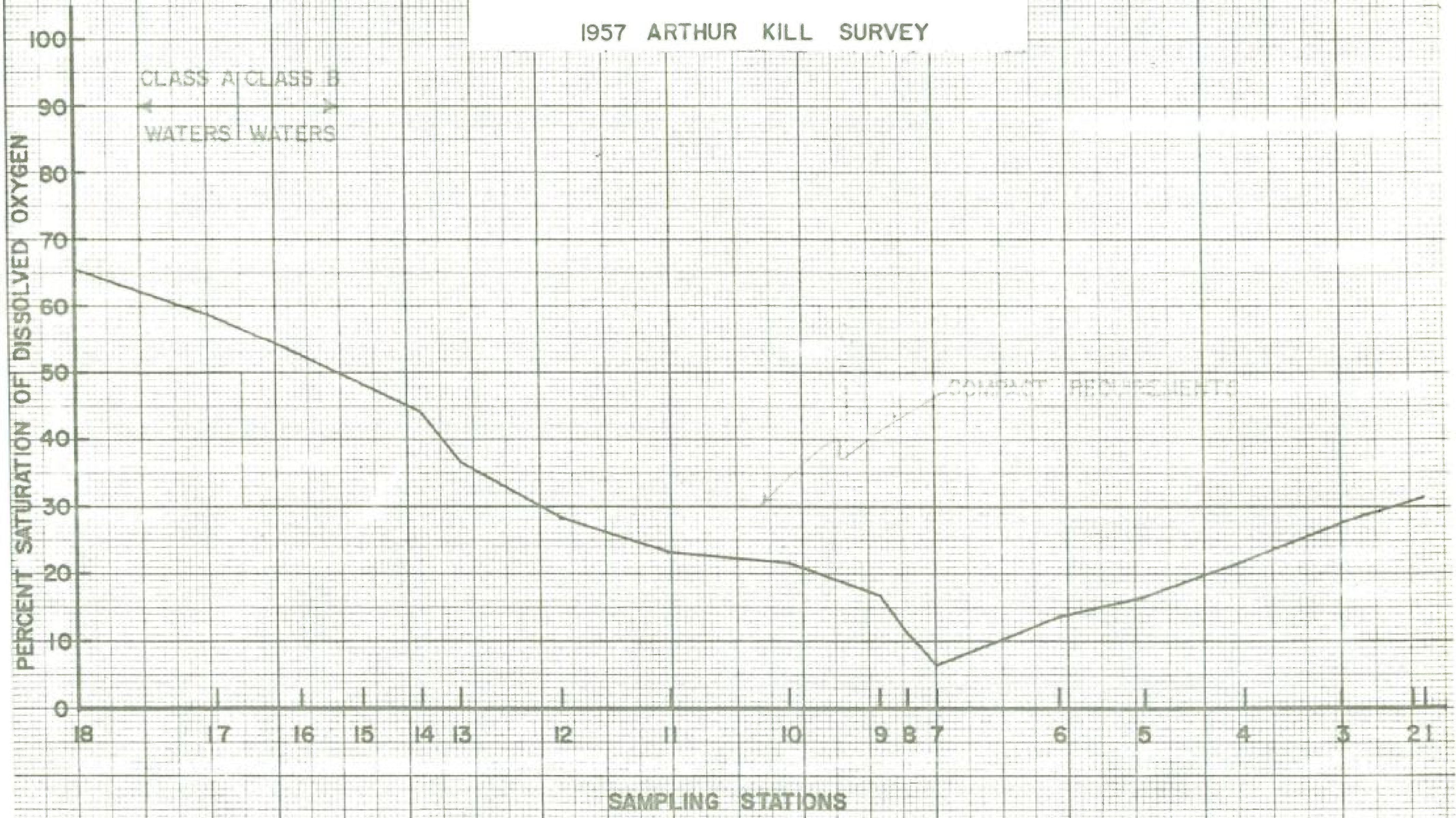


PLATE I

Table I

WEIGHTED MEAN PERCENT SATURATION OF DISSOLVED OXYGEN

STATION	WEIGHTED MEAN % SATURATION
1	31.2
2	29.3*
3	27.6
4	22.0
5	16.7
6	13.7
7	6.5
8	11.3
9	16.8
10	21.7
11	23.2
12	28.3
13	36.7
14	44.0
15	37.5*
16	53.0
17	58.3
18	65.6

* Values not used in % Saturation Profiles

area of New York, and another the Union and Middlesex Counties in New Jersey. Every industrial and domestic waste outlet was reported for the entire length of each side of the Arthur Kill. These revised maps of the Arthur Kill waterway are in Appendix B and range from Perth Amboy to Elizabeth in New Jersey and from Port Ivory to Tottenville in New York.

5) Industrial Wastes 1950-58

In 1950, the Industrial Waste Survey of this Commission listed the industrial wastes discharged directly into the entire District by way of private sewers. The Arthur Kill was again part of this overall project.

In 1958, the Commission conducted another limited survey to supplement the 1950 data. This survey included the industrial wastes that were being discharged into the Arthur Kill waters through public or private sewers without treatment. Each industrial plant completed a questionnaire form pertaining to their particular waste and waste discharges. Since the majority of the industry is situated on the New Jersey State side, the Commission and the New Jersey State Department of Health joined in the investigation of this pollutional problem. From 1957 to the present, the Commission and the New Jersey State Department of Health held joint meetings with the industries in New Jersey that contribute the greatest amount of industrial wastes and acquainted them with the various problems encountered.

WATER POLLUTION SURVEYS

Period 1959-1962

Surveys prior to 1959 were for the basic purpose of establishing whether or not a dissolved oxygen problem existed and if so, its seriousness. During the period from 1959 to present, several detailed investigations were undertaken. They are quite diversified in nature but are all designed to play a very important part in any solution to the existing pollution problem. They include a hydraulic model study, gathering of data for determining the assimilative capacity of the waterway, fish studies pertaining to toxicity and tainting of fish flesh and a more detailed investigation of the industrial waste potential. Some of these studies are now completed and others are being continued. Valuable information obtained thus far allows the solution of some of the "primary unknowns" and the initiation of a comprehensive pollution abatement program in the Arthur Kill area.

Joint Model Study

In 1958, the United States Army Corps of Engineers constructed a hydraulic model reproducing to scale many waterways in the Metropolitan Area including the Arthur Kill. The New York State Water Pollution Control Board, the New Jersey State Department of Health, New York City Department of Health and the Interstate Sanitation Commission, with the latter acting as coordinator, decided in 1959 to conduct a joint pollution study using this hydraulic model. Because of several other higher priority projects, the Corps of Engineers was unable to conduct this joint study until 1961, a delay of one year. Most of the results have been received and the Commission has undertaken an analysis of these data.

The model test consisted of a continuous introduction of pontacyl brilliant pink and uranine dyes into the model at certain selected points, after the model had reached the point of salinity stabilization. The movement of dye is then followed by taking samples of the model water at many points throughout the area of interest. Each sample was analyzed with a fluorimeter to determine the exact concentration present. Although the dye is not intended to represent actual prototype pollution, it is, nevertheless, representative of the movements to which pollution is subjected.The dye is a conservative element (chemically stable), whereas pollution in the prototype is a non-conservative element (chemically unstable). A non-conservative element would exercise an oxygen demand while in an oscillating mass or in the transient motion of leaving the waterway, whereas a conservative element would not decay.

Three discharge points were of primary concern with regard to the Arthur Kill: Passaic Valley outfall, the Rahway River discharge, and the Middlesex County outfall.

The model study confirms the Commission's 1957 Survey to the effect that the continuous ebbing and flooding of the tidal waters in the Arthur Kill causes an oscillatory movement of pollution. Dye introduced at the Rahway River release point oscillated north and south of this point and spread throughout the entire length and with net flow of dye through the northern and southern ends of the Arthur Kill. The main mass of dye oscillated within the limits of the northern mouth of Smith Creek, on the south, and the B & O Bridge on the north. The dye begins to leave the Arthur Kill through both northern and southern extremities approximately one day after it is introduced. The introduction of dye or pollution at any other point within the Arthur Kill would yield similar results with the exception that points close to the extremities would exit more quickly through those extremities, but would still contribute to the oscillating mass of dye or pollution.

It should be noted here that although dye begins to leave the Arthur Kill after one day, there is the retention and build-up of a mass of dye which continually oscillates with the flooding and ebbing currents. This same concentration build-up of a non-conservative element, such as pollution, gives cause to the low dissolved oxygen values of the Arthur Kill. The dye and pollution, which have exited, are not completely free from the Arthur Kill but enter adjacent waters and return on succeeding tidal cycles with lesser effect on each successive tidal phase.

The effect of the Middlesex County outfall release is limited in its influence on the Arthur Kill. From Tufts Point north to Elizabethport, the Middlesex release has an insignificant effect. From Tufts Point south to the outfall, the effect is of significance and supplements the pollutional load originating in the Arthur Kill.

The discharge from the Passaic Valley outfall at Robbins Reef was found to have an insignificant effect on the Arthur Kill. Concentrations of dye from this release point were extremely minute in the vicinity of the mouth of the Rahway River. In projecting this observed transport of dye to the transport of pollution, it appears that the tidal effects in Upper Bay are such as to draw the pollution through the Narrows and out into the Lower Bay on the ebbing phase. The flooding phase does not appear to carry this pollution back through the Kill Van Kull and into the Arthur Kill except in very low concentrations.

Fish Studies - Toxicity and Taste

The model study establishes the fact that pollution moves from the Arthur Kill ("B" water not used primarily for the development of fish life) to the Lower Raritan Bay ("A" water used for the development of fish life). This is most prevalent during the ebb stage of the tide when the Arthur Kill waters are flowing directly into the area. Since there is a large concentration of industry within the Kill, the possible toxic or deleterious effects of chemical and oil pollutants become an issue. In 1961, the Commission requested Doctors James Westman, James G. Hoff and Joseph V. Hunter of the State University of Rutgers, New Brunswick, New Jersey, to conduct a fish study. The purpose of this particular research was twofold:

1) To determine whether certain marine fishes would survive in aerated waters from the Arthur Kill and Kill Van Kull.

2) Whether the responses of these fishes to the lowering of dissolved oxygen would differ between the control waters of Shark River Inlet on the one hand, and the waters of the Arthur Kill and Kill Van Kull on the other.

The experiments were conducted in the late summer of 1961, and four species of fish from Raritan Bay were used. Water for the experiments was obtained at:

1) The Shark River Inlet during high tide,

2) The Kill Van Kull at Buoy No.5 near the end of the ebb tide, and

3) The Arthur Kill at Outerbridge Crossing at low tide.

The waters were always used within a 36 hour period. The conclusions reached as a result of this study are as follows:

1) No apparent toxic effects were observed to fish life when adequate dissolved oxygen was present.

2) On occasion, fish required more dissolved oxygen for survival in the Kill Van Kull water samples than in the Shark River Inlet water.

3) The rate of decrease in the dissolved oxygen was found to be very important.

Over the years, many reports were received on the taste of fish caught in the Lower New York and Raritan Bays, and was labelled as a "harbor taste". Dr. Westman of Rutgers University, at the request of this Commission, set up several experiments to determine the source of this harbor taste. It was long suspected that petroleum by-products were the cause of this unpleasant taste in fish and therefore Dr. Westman simulated conditions by injecting kerosenes and other petroleum products into the testing water. His conclusion is that a taste very similar to the harbor taste can be developed in fish within one week using a concentration of one part per million of a petroleum product. It is felt that this harbor taste can be matched by utilizing lower concentrations of kerosene.

Thus, the waters of the Arthur Kill where they are discharging through the Kill Van Kull or into the Raritan Bay may, at times, exert some toxic effect and impart an unpleasant taste on fish life in the Bays. These two effects are brought about principally by discharges from the chemical and petroleum industries. These studies of pollutional effects on fish life will be continued.

Industrial Waste Investigations

In an effort to determine the characteristics and quantities of the wastes discharged by industries, the New Jersey State Department of Health and this Commission made joint investigations of each industry. These investigations include a sampling of all waste discharges, a determination of flows and a detailed report which sets forth the pollutional potential of each industry. These reports were prepared by industry at the joint request of both control agencies. Most have submitted these reports and the others are pending.

This program has helped define the types and quantities of wastes to be considered and to place the direct industrial discharges in the correct perspective. All discharges are considered from the standpoint of biochemical and immediate oxygen demands and the thermal effect on the dissolved oxygen concentration in cooling waters.

A preliminary investigation has shown that at the three generating stations located along the Arthur Kill over one billion gallons per day of brackish water is being utilized for cooling purposes. The higher temperatures imparted to incoming water may result in a substantial loss of dissolved oxygen over the period of a day. These stations are believed to be very important in regard to thermal pollution and therefore careful field investigations are being made. The effluents also tend to raise the overall temperature of the Arthur Kill and thereby increase the biological activity.

In this thermal pollution investigation, the cooling processes of other industries have not been overlooked. With regard to these industries, more temperature and dissolved oxygen samples will be taken of influents and effluents to give a more accurate evaluation of thermal pollution and its effect on the Arthur Kill. The seriousness of the thermal aspect is not fully known at present; however, it is felt that it will become more important as the quality of the water improves.

Total Quantity of Pollution Discharged

Domestic Sources

Since 1936, the Commission has sampled the domestic waste treatment plants within its jurisdiction. The Arthur Kill today has six primary sewage treatment plants discharging their respective effluents directly into the Arthur Kill. Table II lists the total pollutional discharge of these six plants. In 1957, one of these effluents was not discharging directly into the Arthur Kill. This particular effluent started discharging into the waterway in 1959, at the most critical oxygen deficit area. The development of Staten Island, New York is expected to proceed rapidly, after the completion of the Narrows Bridge. This will bring more wastes into a waterway which is already in critical condition. Most of the domestic sewage is receiving primary treatment; however the reduction in B.O.D. is insufficient.

Industrial Sources

Of the 30 industries located on both shorelines of the Arthur Kill, approximately 24 discharge liquid wastes directly into the waterway. These wastes contain primarily soluble B.O.D. and primary treatment alone would be inadequate. The pollutional effect of these industries is reflected in Table II. In addition to the B.O.D. discharges, there are other materials being discharged by some industries that consitute a violation of one or more of the previously stated standards. Since 1957, the overall number of industries, as well as the volume of pollution, has remained fairly constant. However, one new generating station (in New York) was erected in the critical area (Station 7) and the other two stations had extensive expansion programs. These changes have resulted in the consumption of an additional 500 million gallons per day of Kill water for cooling purposes. This results in a higher temperature of the Kill water and consequently a greater exertion of the biochemical oxygen demand. New York City is planning an industrial park (1968) in the northern area of the Arthur Kill shoreline and this is expected to result in additional pollution in the waterway.

Table II

QUANTITY OF POLLUTION DISCHARGED
to the ARTHUR KILL
(1962)

Source of Pollution	Average Daily Flow (MGD)	Average Effluent BOD/Day #	% of Total Effect (BOD)
Domestic Plants (6)	93.7	122,000	47
Industrial Plants (24)	303.1	140,000	53
Total	396.8	262,000	100

Collection of Supplementary Prototype Data

To obtain data necessary for the determination of the assimilative capacity of the waterway, four shoreline sampling points in the Arthur Kill were selected. Each of the points was so located that good representative samples of the waters of the Arthur Kill were obtained. Previous studies by this Commission indicated that there is good horizontal and vertical mixing and that stratification is not a problem. All four shoreline stations are so located that they are within the section of the Arthur Kill which was below Compact requirements during the 1957 survey. Shore Station 2 is located at the section of critical deficit within the Arthur Kill. A description of the location of each of the four shore stations is as follows:

STATION 1S Location is on the New Jersey shoreline of Arthur Kill at the intersection of the property lines of the Elizabeth Loizeaux Cement Company and the California Oil Company.

STATION 2S Located at the American Cyanamid Plant on the shoreline of the Arthur Kill just north of Rahway River.

STATION 3S Located at the loading dock of the General American Tank Storage Company on the shoreline of the Arthur Kill.

STATION 4S Located at the end of the U. S. Metals Refining Company dock which extends about 400 feet into the channel of the Arthur Kill.

With the cooperation of industry, arrangements were made for members of the Commission staff to take samples at various times at these four shoreline points. Samples were taken at half hour intervals for a period of five hours on Mondays through Thursdays, for two week periods, at different times of the year. Table III gives the average values for the most critical condition observed at Station 2S. All samples were taken and analyses made in conformance with the "Standard Methods for the Examination of Water, Sewage and Industrial Waste."

DETERMINATION OF WASTE TREATMENT REQUIREMENTS

The Commission's approach for determining the necessary reduction in B.O.D. discharges in the Arthur Kill involves a utilization of the oxygen sag curve equation and specifically as it pertains to the point of critical deficit. The critical dissolved oxygen deficit occurred at Station 2S, thus making it the point of primary concern. The values obtained at this station were utilized in the determination of the treatment requirements. Of all the data gathered, only that pertaining to the lowest dissolved oxygen level reached are of any value in this present report. Stations 2S and 3S were sampled more frequently because of their locations in the section of critical deficit in the Arthur Kill. It is felt that the data obtained are representative of the effects created by the discharges within the Arthur Kill from many points along the shoreline.

The oxygen sag curve theory and applications are well documented in the existing literature and will not be reviewed here. It will suffice to say that at the point of critical deficit the effects of the deoxygenation and reaeration are in balance. Therefore, the oxygen sag curve equation reduces to the following:

$$D_c = \frac{k_1}{k_2} L_o \times 10^{-k_1 t_c}$$

Where:

D_c = the dissolved oxygen deficit at the point of critical deficit in the waterway and expressed in parts per million.

k_1 = the deoxygenation coefficient of the water under investigation, and at the temperature under consideration.

k_2 = the reaeration coefficient of the waterway under investigation, and at the temperature under consideration.

L_o = the ultimate biochemical oxygen demand of the water under investigation, at the temperature concerned and expressed in parts per million.

t_c = the time in days, necessary for pollution to pass from the point of introduction into the waterway to the point of critical deficit.

In equation (1), t_c is the time of transit for pollution from a reference point, or source, to the point of critical deficit. The amount of ultimate biochemical oxygen demand in the water, at a reference point for a particular source, will decrease as it passes to the point of critical deficit. At the latter point, a certain residual amount of oxidizable organic material will be present and reflect a certain ultimate biochemical oxygen demand. The relationship

$$L_t = L_o \times 10^{-k_1 t_c}$$

may be utilized to compute the ultimate B.O.D., L_t, at the point of critical deficit, after some time, t_c. If samples are taken at the point of critical deficit, this value L_t or L_c can be observed and there will be no necessity to compute it. Therefore, the value t_c in the above equation becomes zero and reduces the term

$$L_o \times 10^{-k_1 t_c} \text{ to } L_o$$

L_o will equal L_c since the samples are taken at the point of critical deficit and there is zero time of passage involved. Thus, equation (1) may be reduced to the following:

$$D_c = \frac{k_1}{k_2} \times L_c \qquad (2)$$

Given a particular condition, the ratio, $\frac{k_1}{k_2}$ becomes a constant and D_c will vary directly with L_c. Thus, if it is necessary to reduce a specific deficit by a certain percentage, to meet a minimum water quality standard, then it will be necessary to reduce L_c by the same percentage. L_c is a direct result of the pollutional material applied to th waterway and any necessary percent reduction in L_c is also necessary in the pollutional material discharged. These relationships are as they may apply to fresh water streams with a given flow in one direction.

Adaption to Tidal Waters

Figure I serves to illustrate a part of the Arthur Kill with a pollution source, at outfall (1) and the resulting point of critical deficit. If this outfall is the only source of pollution, then the deficit created at the critical point is due entirely to this one source. However, the Arthur Kill is a tidal waterway which causes the pollution to move quickly back and forth with the flooding and ebbing currents, but the net movement of pollution away from its source is slow compared with a fresh water stream with flow in one direction only.

Part of the pollution put into the Arthur Kill on a particular day will move away from the point of introduction and not return; however, part of it will return. The amount which remains or returns on succeeding days decreases with time and may vary consierably, depending upon the waterway. However, when considering a continuous discharge of pollution, a cumulative effect is produced and any ultimate biochemical oxygen demand, L, observed in the waterway may be composed of organic material which has been in the waterway for various periods of time ranging from a few minutes to days prior to the time that a sample is taken. Thus, when considering, as in Figure I, a single outfall and its resulting point of critical deficit, the t_c value becomes zero in the following expression:

Figure I

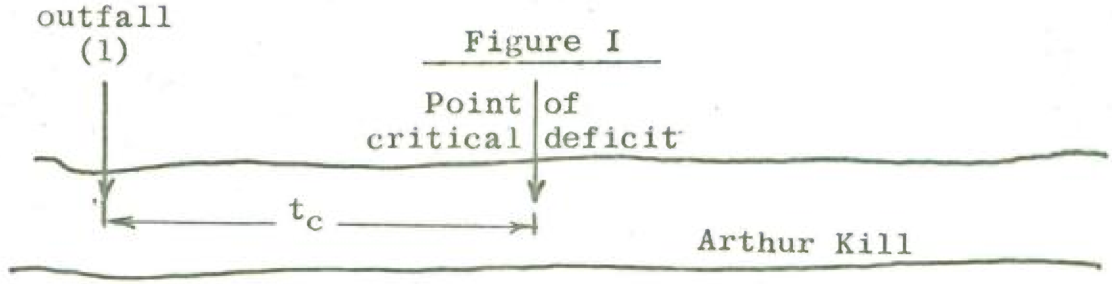


Figure II

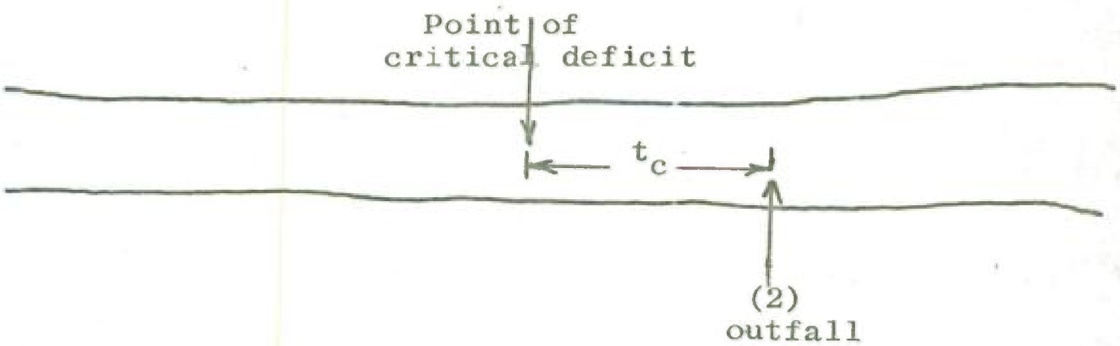
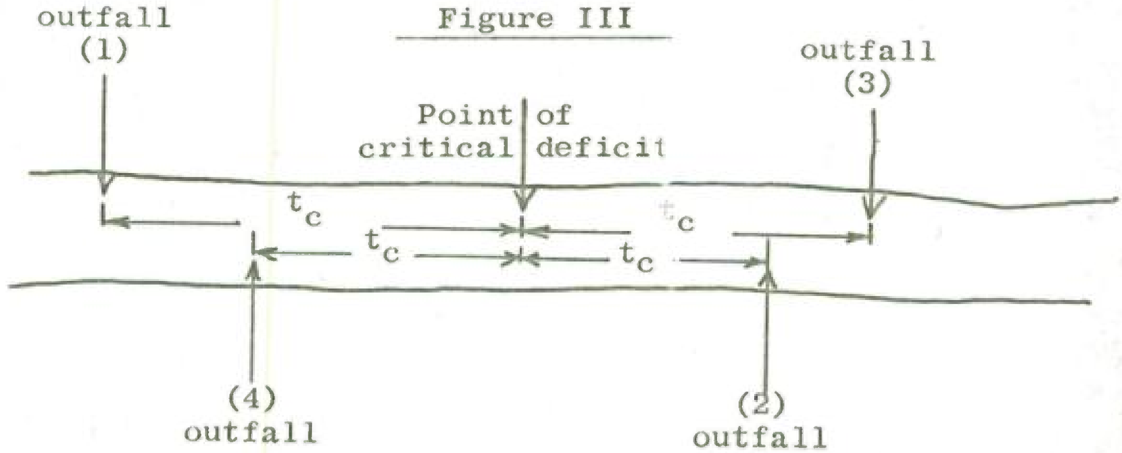


Figure III



$$L_t = L_o \times 10^{-k_1 t_c}$$

when for tidal waters we set:

L_o = the average ultimate biochemical oxygen demand of the water under investigation, at a particular reference point, after a condition of equilibrium has been reached between pollution discharge, its build-up in receiving waters, deoxygenation and reaeration for the temperature concerned. It is expressed in parts per million.

L_t = the average ultimate biochemical oxygen demand of the water under investigation, after some time "t" or it may be "t_c" from the particular reference point and after a condition of equilibrium has been reached between pollution discharge, build-up in receiving waters, deoxygenation and reaeration for the temperature concerned. It is expressed in parts per million.

t_c = the time, in days, necessary for pollution from a source to travel to and reach a condition of equilibrium between pollution discharge, build-up in the receiving waters, deoxygenation and reaeration, for the temperature concerned, at the point of critical deficit.

k_1 = the deoxygenation coefficient of the water under investigation and at the temperature being considered.

L_c = the same as statedfor L_t except that this is the value which exists at the point of critical dissolved oxygen deficit only.

Using this procedure, equation (2) may be applied to tidal waters for the conditions stated and D_c will vary directly as L_c.

In Figure II, outfall (2) is now used to illustrate the introduction of pollution from a single source in a different location and which creates a point of critical deficit as shown. The same reasoning used in the case of Figure I applies here. The value of t_c for outfall (2) becomes zero if L_c is observed directly by sampling at the point of critical deficit. By considering two individual waste sources separately, it is possible to reduce the oxygen sag curve equation, in each case, to equation (2).

Figure III now shows four separate sources of wastes. The waste from each discharges directly into the Arthur Kill, distributes itself quickly, contributes to a build-up of pollution and the creation of a point of critical deficit, where deoxygenation and reaeration are equal. Since the waste from each outfall contributes to the point of critical deficit and t_c in equation (2) for each outfall becomes zero (when the ultimate biochemical oxygen demand value is determined at the point of critical deficit by sampling) then, t_c for all outfalls contributing to the point of critical deficit becomes zero and the relationship described by equation (2) is valid for use in the tidal waters of the Arthur Kill.

The average values for the most critical condition observed at Station 2S are presented in Table III. The Interstate Sanitation Commission standards require an average of not less than 30 percent saturation of dissolved oxygen during any week of the year. Therefore, for the worst condition observed at the point of critical deficit, the water could have contained 7.14 parts per million of dissolved oxygen at 100 percent saturation. Under these conditions, the 30 percent saturation standard requires a dissolved oxygen concentration of 2.14 ppm. The additional amount of dissolved oxygen necessary to reach the 30 percent saturation level is 1.80 ppm (2.14 - .34 = 1.80). Therefore, the necessary percent reduction in the critical deficit may be calculated as follows:

$$\frac{1.80}{6.80} \times 100 = 27\%$$

Thus, to raise the dissolved oxygen level, at the worst observed time, to 30 percent saturation it is necessary to effect a 27 percent reduction in the critical deficit. As stated previously, L_c varies directly as D_c, therefore, it will be necessary to reduce the ultimate oxygen demand at the point of critical deficit by 27 percent. The ultimate oxygen demand measurable at the point of critical deficit is directly related to the waste applied to the waterway through the various outfalls. Thus, a 27 percent reduction in the total biochemical oxygen demand discharged from each outfall will be necessary to bring the dissolved oxygen level up to 30 percent of saturation.

Table III

AVERAGE VALUES
for the
MOST CRITICAL CONDITION OBSERVED
at
STATION 2S

	Dissolved Oxygen		
Temperature (°C)	Concentration in Water (ppm)	Concentration for 100% Sat. (ppm)	Deficit (ppm)
27.2	.34	7.14	6.80

Since a 27 percent reduction in the applied B.O.D. is necessary, this leaves 73 percent of the present discharge or something less than 190,000 pounds of B.O.D. per day as the assimilative capacity of the Arthur Kill waterway with its present distribution of wastes. At the present time, practically all of the B.O.D. discharged directly to the Arthur Kill is from domestic and industrial sources in New Jersey. For all practical purposes, New Jersey is at present exceeding the entire assimilative capacity of the waterway. In this pollution abatement program, consideration must be given to the rights of the State of New York, and specifically, to Staten Island, New York City. New York State is entitled to one-half of this assimilative capacity. Thus, New Jersey will have to effect an additional 37 percent reduction in B.O.D. discharges or a total of 64 percent reduction in the present total pounds of B.O.D. being discharged. This does not allow any margin of safety in computations or allow for future growth and expansion of present city and industrial developments. Therefore, treatment plants must be designed to effect at least a 75 percent reduction in the present total pounds of B.O.D. discharged per day or full secondary treatment with an 80 percent B.O.D. reduction, whichever produces the lower effluent B.O.D. This will allow some margin of safety in computations and for future growth.

SUMMARY AND CONCLUSIONS

1) The dissolved oxygen requirements of the Interstate Sanitation Commission are not being met in the Arthur Kill.

2) Domestic sewage treatment plants are not providing the necessary B.O.D. removal.

3) The industrial wastes which exert an oxygen demand contain primarily soluble B.O.D.

4) On occasions, the waters ebbing through the Kill Van Kull contain substances which increase the minimum dissolved oxygen level required to sustain fish life.

5) Petroleum products create a taste in fish flesh very similar to what is called the "harbor taste".

6) It is believed that kerosene dosages of less

than one part per million will reproduce the "harbor taste".

7) A continuing investigation of thermal pollution is expected to establish dissolved oxygen requirements for cooling water discharges.

8) Industries discharging wastes without an oxygen demand must provide treatment so as to comply with remaining industrial wastes standards.

9) Industries discharging wastes containing any immediate dissolved oxygen demand must satisfy 100% of any such demand prior to discharge.

10) Pollution discharged directly into the Arthur Kill is distributed quickly throughout the entire waterway.

11) Part of the domestic and industrial wastes entering the Arthur Kill at a point opposite the mouth of the Rahway River passes out of the northern and southern ends of the waterway in approximately one day.

12) Approximately 262,000 pounds of B.O.D. are discharged daily into the Arthur Kill. Forty-seven percent is attributed to the domestic plants and the remaining 53 percent to industry.

13) Shore Station 2S is located in the most critical section and is affected by all waste discharges within the Kill.

14) Any comprehensive pollution abatement program must require a degree of waste treatment which will raise the dissolved oxygen level at Shore Station 2S to an average value of not less than 30 percent of saturation during any week of the year.

15) With the present distribution of wastes, the assimilative capacity of the Arthur Kill is estimated to be 73 percent of the total B.O.D. affecting Shore

Station 2S or less than 190,000 pounds of B.O.D. per day.

16) New York and New Jersey are each entitled to one-half of the assimilative capacity of the Arthur Kill.

17) To meet existing requirements, domestic and industrial waste treatment plants must be designed to effect at least a 75 percent reduction in the present total pounds of B.O.D. discharged per day or full secondary treatment with an 80 percent reduction in B.O.D., whichever produces the lower effluent B.O.D. These plants must also comply with all other standards.