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WATER QUALITY STUDIES OF THE DELAWARE RIVER WITH REFERENCE TO SHAD MIGRATION

by

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Explanatory Note

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INTRODUCTION

For some time pollution of the waters of the Delaware River by municipal and industrial wastes has been suspected of playing a major role in the decline of the shad fishery. Accordingly, studies were planned to ascertain whether any conditions of water quality caused by stream pollution and harmful or lethal to shad were existant in the waters of the Delaware River during the migration periods of the shad.

Miss Louella Cable, biologist of the Fish and Wildlife Service, reports that the shad fishery in the Delaware River, which was once very extensive in the upper river as far as above Port Jervis, now is confined largely to the lower reaches of the river and bay below Pennsville. In the spring of 1946 about 250 fish were caught by a fisherman operating near Lambertville, N.J.; as many as 9,288 fish were taken in 1896, and varying numbers from a few hundred to several thousand up to 1943. Although shad normally spawn in the river from Philadelphia to beyond Port Jervis, in 1945 live shad eggs and newly hatched fry were found only at the mouth of the Lackawaxen River. The field work, therefore, was planned to ascertain, first the water characteristics of the Delaware River near the usual upper limit of where shad are now taken and, by comparison with the water characteristics of a river in which the shad were migrating successfully, determine those characteristics which were harmful to the shad.

The major disturbing characteristic, low dissolved oxygen, was determined in a reconnaissance survey made during the last week of April and the first week of May, 1946; i.e., during the time of the spring upstream migration of adult shad. In the second week of September, a second series of field studies were made to define the limits of almost oxygen-free water in the Trenton, Philadelphia, Wilmington, sector of the Delaware River. These studies were planned for a portion of the period when the fall downstream migration of young shad should have been in progress. A third series of field studies were completed during the third week of October, that is near the end of the period during which the young shad should be migrating downstream in this section of the Delaware River. These surveys necessarily omitted consideration of conditions in the river during the summer months when spent shad normally return to the sea.

Supplementing the findings from these three series of field observations, preliminary experimental tests on the tolerance of young shad to low oxygen were made at the Harrison Lake, Virginia hatchery during the first week of November. Data from these preliminary experimental studies have been used in part of the present report.

From the three sets of field operations on the Delaware River, extensive collections of samples were returned to the laboratory for analyses and tests not feasible in the field. In both the field and laboratory work, the procedures outlined in Research Report Number 9, U.S. Fish and Wildlife Service (1) were followed in general, except where special methods not listed in that publication were required.

The writers wish to express their thanks to Messrs. R.O.Jones, A. S. Hale and G. C. Rau and Mrs. M. D. Ellis, all of whom participated in both the field operations and the many analyses required in these studies.

April-May, 1946, Reconnaissance Survey

The field work in this survey extended from April 27 to May 4, 1946, inclusive. The party, consisting of Dr. B. A. Westfall and Mr. W. S. Platner, conducted operations from a laboratory truck and from motor boats.

The major sampling section (hereafter referred to as the Pennsville, New Jersey section or as Section J) for the reconnaissance survey extending across the Delaware River from Pennsville to a little north of Newcastle (see descriptive list of sampling stations) was selected not only because few shad were reported above it, but also because the river in this section carried the combined effluents and wastes, both municipal and industrial, from the Trenton, Camden, Philadelphia, and Wilmington, areas (See Figures 10 and 11).

The water of the Delaware River in the Pennsville section is brackish to salt and is subject to definite tidal fluctuations. As the Pennsville Section crosses the Delaware River where it is narrowed into a river, i.e., where the bay and estuary characteristics have given way to river characteristics the Hudson River at Verplanck, New York, seems to present reasonably comparable conditions to the Pennsville section, and it was therefore chosen as the major sampling section for the Hudson River. (See Figure 10).

As migrating shad were being taken by commercial fishermen in the Verplanck section at the time the water samples reported here were taken, it is evident that these fish had not encountered any water-quality barrier in the Lower Bay and the Upper Bay of the Hudson nor from the waters of the East River.

Other samplings and field observations were made in the Schuylkill in Philadelphia; in the Delaware at Burlington, New Jersey, below Easton and near Stroudsburg, Pennsylvania, and above Port Jervis, New York; and in the Hudson at Waterford, New York. Some of these are reported in Table 2. Numerous "spotting" samples were taken as well.

Of the 12 major and several minor water characteristics determined from all stations (see Tables 1, 2 and 3), the only one out of bounds in terms of the commonly accepted standards of water quality for fish was dissolved oxygen. The dissolved oxygen was dangerously low, 2 p.p.m., near the low tide stage in the Pennsville, New Jersey, section at the mid-channel mid-depth Station J 5 and was almost absent, 0.4 p.p.m., in the Schuylkill River at the Penrose Ferry Bridge, Section D, in Philadelphia. All other water characteristics of this section of the Delaware were essentially the same type as those of the Hudson River section at Verplanck, New York, which is in a sector of the Hudson through which a run of shad was migrating upstream at the time the samples were taken.

In Table 1 the data on 12 major water characteristics are given for the mid-channel, mid-depth station in the Pennsville section at two-hour intervals throughout a 12-hour tidal cycle. The mid-channel, mid-depth station in this section is presented because at such a station in any river the mixing of the various components causing changes in these components must be of considerable magnitude to affect specific water characteristics. In other words, if changes are found in the water characteristics at a mid-channel station during any given period, these changes are generally significant.

In Table 1 it can be seen that the dissolved oxygen declined from 5.3 p.p.m. at 7:00 A.M. to 2.0 at 11:00 A.M. During these four hours there was also a drop in both the specific conductance and chlorides indicating that the less salty water from upstream in the Delaware and Schuylkill was following the outgoing tide. This fresh water from the Schuylkill and Delaware as subsequent analyses showed was a mixture containing very little dissolved oxygen (See Table 2), and considerable material having marked oxygen demand. As dead low tide fell between the 9:00 A.M. and 11:00 A.M. samples in this particular instance, it is not known how much lower than 2.0 p.p.m. the dissolved oxygen may have dropped just before the tide turned.

With the return of the tide the dissolved oxygen rose from 2.0 p.p.m. at 11:00 A.M. to 6.1 p.p.m. near dead high tide. Again the specific conductance indicated the movement of the more salty water, this time upstream. This mass of more dense, more salty and well aerated water as it moved upstream pushed the less dense fresh water of low dissolved oxygen content upstream and consequently the dissolved oxygen at the mid-channel station in the Pennsville section rose as has already been noted.

After dead high tide near 3:00 P.M. the more dense salty water began to recede to be followed by the downstream movement of the fresh water of low oxygen content from upriver, and again the dissolved oxygen at the mid-channel station fell, reaching the 4.5 p.p.m. level at 7:00 P.M. at which time the tide was moving out rapidly although the dead low stage had not yet been attained.

From Table 1 it seems that water very low in dissolved oxygen is drawn downstream from the Trenton-Wilmington sector by each receding tide and pushed back again upstream by each succeeding incoming tide. It is also apparent from the actual values obtained at the mid-channel station in the Pennsville section that the most downstream section attained by this mass of less salty water of low dissolved oxygen content before it is dissipated by mixing with the more salty water from downriver is in the vicinity of the Pennsville section. As the tension zone where the front of this mass of water of low oxygen content breaks by mixing with the upbound water is in the section of the river where the shad migration appears to stop the effectiveness of this barrier is suggested.

In Table 2 the water characteristics of several stations in the Delaware and tributaries are presented for comparison. In this table it can be noted that at a mid-channel mid-depth station near the mouth of the Schuylkill in Philadelphia, the dissolved oxygen was only 0.4 p.p.m. at the time of these studies.

Data obtained during these studies, together with data previously accumulated by the Fish and Wildlife Service, show that this mass of poorly oxygenated water, which in general carries less than 2.0 p.p.m. of dissolved oxygen except very near the surface, extends upstream from the Pennsville section to near Burlington, New Jersey. There was, therefore, at the time of these studies and at the time when the shad were attempting to migrate upstream, a slug of almost oxygen-free water approximately 40 miles long, filling the entire Delaware River from near Pennsville to near Burlington. In order to complete their upstream migration, the shad would be forced to traverse this 40 mile sector which, in view of known facts concerning the respiration and general physiology of the shad, would be impossible. Hence the breakdown of the spawning run of shad near Delaware City as previously noted by Miss Cable and others.

It was suggested in view of the findings of the April-May reconnaissance survey together with other data that because of the large amount of almost oxygen-free water between Beverly and Pennsville, this sector constituted a lethal barrier to the migrating shad. The causes producing the low oxygen in this sector of the Delaware River are primarily municipal sewage, industrial wastes and waste oil.

September, 1946, Studies

A field party consisting of Dr. B. A. Westfall and Messrs. D. K. Meyer, W. S. Platner and G. C. Rau, returned to the Delaware River on September 19, 1946, for a series of samplings and analytical studies which continued through September 21, 1946. This party determined the existence and extent of the mass of almost oxygen-free water which was hinted at as lying between Pennsville and Beverly, New Jersey, by the previous work and also collected samples for all of the major water characteristics so that a comparison could be made with the April and May samples at Pennsville, New Jersey and Verplanck, New York.

Eleven major sections of the Delaware River were studied between Delaware City and Trenton (see Figure 11) compared to one section in the spring survey. These sections included one below the Pennsville section, eight sections through the heavily polluted area between Pennsville and Burlington, and two in the Burling-Trenton sector. In general three sampling stations were selected on each section, namely a mid-channel station for reasons already discussed, and two lateral stations, one on each side of the channel. At each of these stations samples were taken at three levels, near the bottom, at mid-depth and near the surface. At most of these stations, samples were collected during two or more phases of the tide cycle.

The date from these field studies are presented in Tables 4 to 21, inclusive.

The findings of the September survey which was scheduled at the time the downstream run of young shad should have been in progress, may be summarised as follows. The mass of water of very low dissolved oxygen content (2 p.p.m. or less) extended from shore to shore and from surface to bottom, from Pennsville to Riverton, a span of between 35 and 40 miles by river. Both the Pennsville and Riverton sections were markedly influenced by tide, i. e., these two sections were the terminal tension zones in which the almost oxygen-free water mixed with fairly well aerated water. Dissolved oxygen was the only water characteristic which deviated from the standards of water accepted by the Water Quality laboratory as not harmful for fish.

October, 1946, Studies

A third field party composed of Dr. M. M. Ellis, Messrs. R. O. Jones and A. S. Hale and Mrs. M. D. Ellis worked on the Delaware River in the Trenton, Delaware City sector October 18 to 24 inclusive, 1946. All of the sections studied by the September party were revisited and after "spotting" tests and general observations had been obtained, detailed studies of 5 of the 11 Sections (A, D, F, J and L) were made. The primary objective of this survey was the determination of the limits of the mass of almost oxygen-free water near the end of the fall downstream migration of the shad.

The data collected by the October survey have been assembled in Tables 22 to 28 inclusive. The findings of the October party were essentially the same as those of the September and April-May surveys, namely that the low dissolved oxygen is the conspicuous harmful water characteristic in this sector of the Delaware River and that no other disturbing water characteristics were found. The mass of water of very low dissolved oxygen content (2 p. p. m. or less) extended from shore to shore and from surface to bottom from Pennsville to about 5 miles below Riverton, that is for 35 to 40 miles depending upon the stage of the tide. The details of these findings together with those of the April-May and September studies* are considered collectively in the following section.

Discussion

Although dissolved oxygen has been listed under each of the three surveys as the major detrimental water characteristic in the Trenton, Delaware City sector of the Delaware River, it is desirable to review the other water characteristics collectively before considering the details of the low oxygen problem. At the time the April-May, 1946, survey was begun the water characteristics, if any, responsible for the interruption of the shad migration in the Delaware River had not been determined. Therefore, in spite of the fact that low dissolved oxygen had been noted previously in this sector of the Delaware River by the U. S. Army Engineers (2) and the New Jersey authorities (3), 12 major and several minor water characteristics were included in the analyses of the April-May, 1946, samples to ascertain which were significant in evaluating the effects of pollution on shad migration in the Delaware River.

Reviewing tables 1-21 inclusive, and 24 and 26, the carbonates, sulfates, phosphates, calcium and magnesium are found to be well within the limits expected in inland waters supporting good fish populations (4) and also within the limits of the analyses of waters from sectors of the Hudson, the James, the Chickahominy and the Chowan Rivers in which shad are known to migrate freely, and from the Harrison Lake, Virginia hatchery ponds in which young shad were being raised successfully.

The chlorides and simultaneously the specific conductance vary greatly in the Delaware River over a much wider range than would be expected in inland waters unaffected by tide and salt water. Although the chlorides are higher in streams receiving quantities of domestic sewage, the very high chlorides and specific conductance of the waters of the Delaware River in the Pennsville section (tables 1, 20, 21 and 27) and the Delaware City section (tables 18 and 19), and of the Hudson River at Verplanck, New York (table 3) are clearly due to the tidal encroachments of salt water. This is readily confirmed by comparison of the chlorides and specific conductance of samples taken at the same station at different times during the tide cycle. As the chlorides quite overwhelm the other ions contributing to the specific conductance of these waters, specific conductance can be taken as the approximate measure of the salinity of these waters and therefore of the tide stage.

The hydrogen-ion concentration, pH, of all samples was determined with a glass electrode pH meter. The pH of the water of the Delaware in the Trenton, Delaware City sector ranged between pH 6.4 and pH 8.3. Water more alkaline than pH 7.9 however, was found only in the Delaware City section, where pH 8.2 and pH 8.3 were recorded. This is not surprising as the specific conductance, chlorides and other characteristics show that the water of the Delaware River at Delaware City is definitely salt and that ocean water from the bay dominates in determining the water characteristics in this section.

From the Pennsville section which is the tension zone between the salt and fresh waters, upstream to Trenton of the 225 pH determinations reported in the tables, 218 lay between pH 6.6 and pH 7.7, with 192 falling between pH 6.7 and pH 7.5.

The entire series of pH determinations on all of the samples of Delaware River water studied in these surveys is within the range of pH tolerated by normal fish fauna of inland streams. As young shad at the Harrison Lake, Virginia hatchery were living and apparently thriving in water at pH 6.6 to pH 6.9 and adult shad migrated successfully in the Hudson River through water at pH 7.3 to pH 7.7, both acidity and alkalinity are eliminated from the list of possible harmful characteristics in the Delaware River sector under consideration. However, these pH determinations are significant not only because they fall in the innocuous range but also because of their bearing on the ammonia problem.

Ammonia in amounts greater than 1 p.p.m. usually indicates organic pollution in stream and river water and 2.5 p.p.m. is near the maximum amount which can be tolerated by fish under average stream conditions without detrimental effects (4). However, the toxicity of ammonium compounds for fish is greatly enhanced as the alkalinity of the water is increased, especially after pH 8 is attained. In waters less alkaline than pH 8, the toxicity of ammonium compounds for aquatic animals is materially reduced so that 2.5 p.p.m. or more may be tolerated.

The ammonia content of the Delaware River water samples (see tables 1-21 inclusive) varied from 0.1 p.p.m. to 4.8 p.p.m. Of the 74 determinations recorded, 53 were between 1 and 5 p.p.m., and 40 between 1 and 3 p.p.m. The ammonia in the Hudson River at Verplanck, New York, during the spring upstream run of shad (see table 3) varied between 1.3 and 3.6 p.p.m. The ammonia was high therefore in both the Delaware and Hudson Rivers in terms of unpolluted streams and indicated marked organic pollution for both rivers. However, the pH of both streams was less alkaline than pH 8, the Delaware being slightly more acidic than the Hudson. In view of the fact that shad were migrating successfully upstream through water in the Hudson carrying up to 3.6 p.p.m. of ammonia at pH 7.3 (see table 3), it must be concluded that shad can tolerate that amount of ammonia in water no more alkaline than pH 7.3.

The amounts of ammonia in the Trenton-Delaware City sector of the Delaware River were definitely higher than in the Hudson and considering other experimental and field data (5) very near the dangerous level for fish even though the pH was definitely less alkaline than pH 8. However, the ammonia hazard to the shad in this sector is probably secondary to the hazards of low oxygen. The amounts of ammonia are above the dangerous level for fish in the existing pH range of the Delaware waters but the dissolved oxygen in these same waters was found to be at definitely lethal levels. The same organic pollution which is one of the major agents reducing the dissolved oxygen in the Delaware River to small or negligible amounts is also the cause of the high ammonia found in this sector. Elimination, therefore, of the causes of low oxygen will also eliminate the high ammonia.

Extensive tests were made for heavy metals including copper, iron, lead, zinc, tin, antimony, and arsenic as small quantities of some of these elements have been the cause of insidious but lethal pollution in other waters. However, no significant quantities of any of these elements were found. The phenolic compounds in the Hudson River and in the Delaware water samples were essentially the same and were not present in significant amounts. Tests for sulfides, mercaptans, noxious sulfur compounds and various organic substances which might be lethal to fish were all negative or showed the quantities present to be too small for consideration. Therefore, from all the analytical studies made both in the laboratory and the field, the most detrimental water characteristic found was the low dissolved oxygen content with ammonium compounds also a hazard should the amounts of these compounds be increased or should the alkalinity of these waters of this sector of the Delaware be raised to above pH 8.

It is the author's experience that under stream or lake conditions the reduction of dissolved oxygen to 3.5-3.0 p.p.m. at summer water temperatures and to 2.0 p.p.m. at winter water temperatures is lethal for many species of fish in 48 hours or less. Also that the tolerance of fish to low oxygen is reduced in polluted waters. As this subject of low oxygen has been reviewed many times, the reader is referred to published articles (1, 4, 6,7,8). Throughout this report 2 p.p.m. dissolved oxygen has been referred to, therefore, as critically low for fish life. All analyses for dissolved oxygen reported in the data tables were made by the sample-blank modification of the Winkler method (1) and are fully corrected for all substances which could disturb the Winkler procedure, i. e., the values tabulated are true dissolved oxygen values.

From the data collected during the September survey it can be noted that from Bridgeport to Riverton, New Jersey, (high tide only) inclusive, the dissolved oxygen at all points studied, that is at the surface, mid-depth and bottom levels for the lateral and mid-channel stations, inclusive, was below 3 p.p.m. (See tables 4 to 11 inclusive and 13 to 15 inclusive.) This statement is made regardless of the phase of the tide except for Riverton where high tide only is included. Of the 113 oxygen determinations in this group of sections, 66 were below 0.5 p.p.m., 78 below 1.0 p.p.m. and only 13 above 1.99 p.p.m.

In figure 1 profiles of the dissolved oxygen levels at the mid-channel mid-depth stations are given for the Trenton - Delaware City sector. In this figure, it can be seen that the almost oxygen-free water at Bridgeport is drawn downstream to Pennsville during low tide and that well aerated water is drawn down to Riverton at the same time. At high tide some oxygen-carrying water is forced upstream from the Pennsville section to Bridgeport raising the dissolved oxygen there from less than 0.5 p.p.m. to almost 2 p.p.m. and at the same time, water almost devoid of dissolved oxygen is forced upstream from the Delaware Bridge section to Riverton, reducing the dissolved oxygen there from above 5 p.p.m. at low tide to less than 1 p.p.m. at high tide. Riverton and Pennsville are, therefore, the tension zone sections. The exact configurations of these tension zones vary with wind, wave action, the temperature, tide, stage of water and shoreline configuration. For example, on September 21, 1946, in the Pennsville section (table 20) at low tide, the dissolved oxygen on the New Jersey side was 4.9 p.p.m. at the bottom, 3.9 p.p.m. mid-depth and 3.9 surface, while on the Delaware side, the dissolved oxygen was 1.7 p.p.m. at the bottom, mid-depth and surface. The mid-channel dissolved oxygen values fell about midway between the New Jersey and Delaware station values.

If the 2 p.p.m. level of dissolved oxygen be projected across the graphs in figure 1, it can be seen that at low tide a mass of water about 35 miles long from near Pennsville to between Delaware Bridge and Riverton carried less than 2 p.p.m. dissolved oxygen. Similarly at high tide a mass of water more than 28 miles long and extending from below Bridgeport to between Beverly and Riverton carried less than 2 p.p.m. at the mid-channel, mid-depth stations. From the low tide limit of 2 p.p.m. or less dissolved oxygen at Pennsville to high tide limit above approximately 40 miles of river are included in this mass of water carrying less than 2 p.p.m. dissolved oxygen.

Therefore, considering the differences in time of the upstream back-up caused by the incoming tide at the different stations between 30 and 40 miles of river are contained in this slug of water carrying less than 2 p.p.m. dissolved oxygen.

In figure 2 the dissolved oxygen profiles for mid-channel, mid-depth stations are shown for the Trenton-Pennsville sector from data collected during the October survey. The general picture is the same as that just described in detail for the September survey with one difference. The colder water in October carrying more dissolved oxygen above Riverton (see tables 22-28 inclusive) was forcing the heavily polluted water between Delaware Bridge and Riverton farther downstream so that the upper end of the mass of water carrying less than 2 p.p.m. dissolved oxygen lay between Delaware Bridge and Riverton at both low and high tides, but the polluted water was forced down farther into the Pennsville section where the dissolved oxygen at the mid-channel, mid-depth station was 1.57 p.p.m. (see table 27). However, the actual mass of water carrying less than 2 p.p.m. dissolved oxygen although displaced some five miles downstream from its September position in October was still approximately 35 miles long. By consulting the tables (22-28 inclusive) it can be noted that, in those portions of the river where the dissolved oxygen was low, conditions held at all depths and all stations except as influenced by tide in tension zone sections.

In figures 3 to 9, inclusive, dissolved oxygen, ammonia, pH, chlorides and specific conductance have been graphed with reference to the tide phase, for the mid-channel, mid-depth stations in the Pennsville, Bridgeport and Riverton sections. As the Pennsville and Riverton sections traverse the downstream and upstream tension zones respectively, and the Bridgeport section is well in the mass of heavily polluted water, these three sections present a general picture of the critical sector.

From a comparison of figures 3, 4, and 5 which present conditions found during the May, September and October surveys in the Pennsville section, the pH changes are seen to be very small throughout the tide cycle. Specific conductance, chlorides and dissolved oxygen, however, as would be expected in a tension zone where the salt and fresh waters alternately advance and retreat, follow the tide cycle. All three drop during the outbound part of the cycle and rise during the inbound phase.

In the Bridgeport section (figures 6 and 7) the September and October data show pH as relatively stable. The specific conductance, chlorides and dissolved oxygen, as in the Pennsville section, vary with the tide cycle. The actual values for specific conductance and chlorides are much lower than in the Pennsville section as the amount of salt water projected into the Bridgeport section by the high tide is much less than in the Pennsville section. The dissolved oxygen is so low, however, that the small, additional amount of dissolved oxygen brought into the Bridgeport section with the high tide back-up does not change the dissolved oxygen significantly as regards the shad migration, all values for dissolved oxygen in this section being below 2 p.p.m.

The graphs for the upstream tension section, Riverton (figures 8 and 9) show that pH, specific conductance and chlorides are affected little if at all by the tide cycle. The backup of water at high tide, however, forces the almost oxygen-free water found in the Delaware Bridge section upstream so that the dissolved oxygen falls in the Riverton section during high tide and rises during low tide. This is exactly opposite from the changes in dissolved oxygen correlated with tide movements in the Pennsville section.

In all of these figures, the variations in ammonia seem independent of the tide cycles but apparently fluctuate as some other factors change.

Tolerance of Young Shad to Low Oxygen.

Although it is well established that even under field conditions the reduction of dissolved oxygen to the 2 p.p.m. level constitutes a critical and lethal hazard to fish and that under summer water temperatures 3 to 3.5 p.p.m. dissolved oxygen is usually too low to support fish life, both species and individual tolerances to low dissolved oxygen vary. As the present survey is concerned with the specific effects on migrating shad of the water in a sector of the Delaware River in which the dissolved oxygen does not rise above the 2 p.p.m. level, the individual tolerances of 111 young shad of migrating age and condition were obtained in preliminary studies made at the Harrison Lake, Virginia hatchery the first week in November, 1946, by a party consisting of Dr. M. M. Ellis, R. O. Jones, A. S. Hale and M. D. Ellis.

As may be computed from figures 3, 4, 5, 8 and 9, the dissolved oxygen in the tension zones at Pennsville and Riverton was reduced or increased during the various phases of the tide cycle at rates varying from 1 p.p.m. in 30 minutes to 1 p.p.m. in 60 or 70 minutes. These rates are somewhat approximate but show the general rates of oxygen change that a fish remaining in the tension zone during the tide cycle would experience. However, were a fish swimming upstream through the Pennsville section when the tide was moving out or downstream through the Riverton section when the tide was rising, the rate of oxygen reduction to which the fish would be subjected would be more rapid, as in each of these cases the fish would be swimming into the oncoming mass of water carrying little dissolved oxygen.

Accordingly the young shad in the Harrison Lake, Virginia tests were subjected to reduction in dissolved oxygen at rates varying from 1 p.p.m. in 10 minutes to 1 p.p.m. in 65 minutes to simulate conditions encountered by migrating shad in this sector of the Delaware River.

These tests on young shad were conducted at 19-22° Centigrade, temperatures near but below the maximal water temperature recorded by the September survey (see tables 4-21), and at 16° Centigrade which was approximately the minimal water temperature recorded by the October survey (see tables 22-28 inclusive). During the Harrison Lake tests the equipment was adjusted so that the young shad were subjected to no significant changes in water characteristics other than reduction of dissolved oxygen and changes in pH.

When subjected to rapid reduction in dissolved oxygen, young shad rapidly became helplessly incoordinate, swimming violently and erratically in an upside-down position, and then sinking to the bottom where they lay on their backs. These anoxaemic fish often lay on the bottom for some time and frequently made additional sorties of erratic swimming before dying.

The Harrison Lake tests on young shad of migrating age and condition at temperatures which these fish would be subjected to during their fall migration down the Delaware verify the generally reported belief that shad are very sensitive to reduced oxygen. As many of these shad became helplessly incoordinate and died before the dissolved oxygen was reduced to 4 p.p.m. and a few even before it was reduced to 5 p.p.m., any portion of the Delaware River carrying less than 5 p.p.m. of dissolved oxygen must be regarded as presenting a lethal hazard to migrating shad. If the 5 p.p.m. dissolved oxygen level be projected across figure 1 which graphs the dissolved oxygen levels during the September survey and at a time when much of the water was above 23° Centigrade, the sector of water dangerous to migrating shad is lengthened from the 35-40 mile 2 p.p.m. sector to nearly 50 miles for the 5 p.p.m. sector.

Although the analytical studies of the waters of this sector of the Delaware found no water characteristic except low oxygen deviating significantly from the accepted standards and although specific tests for all of the metallic poisons and organic substances which are generally suspected of detrimental action on fish in polluted waters were negative, the possibility still remains that some unidentified substance having specific toxic effects on shad could be present in these waters. That possibility, although remote, has been eliminated largely by bioassays on goldfish using water collected from this sector of the Delaware and maintaining in this water a suitably high oxygen level so that dissolved oxygen was eliminated as a lethal factor. However, regardless of these remote possibilities the fact remains that a sector of water some 50 miles long, carrying so little dissolved oxygen that it constitutes a lethal barrier to shad, stands between the inbound shad and their upstream spawning grounds and between the downbound young shad and the ocean. Until the dissolved oxygen in that sector is raised to above 5 p.p.m. few shad can pass this barrier and hypothetical pollutants can be disregarded.

Since adult shad, as reported by Miss Cable in the spring of 1946 have been caught in the Delaware above the zone of the oxygen barrier and eggs and fry were taken in 1945, it must be assumed that channels or currents of water, containing sufficient oxygen to support fish life while traversing the 40 or 50 mile stretch here described, must occur at times, perhaps only briefly, during the periods of shad migration. Such conditions may occur during floods following heavy rainfall for flash floods of considerable size have been reported for the Delaware River.

The causes of the reduction of the dissolved oxygen in the waters of the Delaware River in this sector are three; municipal sewage, industrial wastes and oil. The amount of municipal sewage entering this portion of the Delaware River can be computed and its oxygen demand estimated with fair accuracy from population statistics of the adjacent areas. The volume of sewage is enormous. Some industrial wastes have high oxygen demands, others little or no oxygen consuming power and still others react with various substances in the water to produce an oxygen demand. To estimate the oxygen consuming power of all of the industrial wastes poured into this sector of the Delaware River is an engineering problem of considerable magnitude. The oil pollution and the oxygen demand which it brings apparently should not exist as there are federal laws prohibiting the introduction of oil or oil wastes into public waters affected by the tides.

Summary

1. Water quality studies and analyses by the U. S. Fish and Wildlife Service on samples collected in the Delaware River between Trenton, New Jersey and Delaware City, Delaware in April, May, September and October showed:

(a) that, the only water characteristic of these waters which deviated significantly from the standards of water acceptable for fish life was that of low dissolved oxygen;

(b) that, no specific substance except perhaps ammonia was found in sufficient quantity to be lethal to fish life,

(c) and that these waters, when well-aerated, would support fish life.

2. Surveys made by field parties in April and May, 1946, at the time when the upstream migration of the shad should have been in progress and during September and October, 1946, when the young shad should have been migrating downstream determined the limits of a mass of water extending from shore to shore and from surface to bottom of the Delaware River extending upstream from near Pennsville, New Jersey, to near Riverton, New Jersey, some 35 to 40 miles long and carrying less than 2 p.p.m. of dissolved oxygen.

3. Data from these same surveys showed that the mass of water in this Pennsville-Riverton sector carrying less than 5 p.p.m. of dissolved oxygen was over 50 miles long.

4. As young shad are very sensitive to dissolved oxygen, and commence dying when the dissolved oxygen is reduced below 5 p.p.m. at temperatures to which the young shad are subjected in the Delaware River at the time of their fall downstream migration, a lethal barrier of water 50 miles long carrying less than 5 p.p.m. and 35 miles long carrying less than 2 p.p.m. of dissolved oxygen stands between the returning young shad and the ocean and the incoming adult shad and their spawning grounds.

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Descriptive List of Sections and Sampling Stations

The following list gives the position of each section and [illegible] studied during the three surveys reported here. The description [illegible] stations have been taken from U. S. Coast and Geodetic Survey [illegible] the Delaware River, [illegible] 295, August [illegible] 19[illegible], [illegible] 19[illegible].

Bridgeport Section A. Four stations across the Delaware [illegible] the "Chester Range," on a line extending from the [illegible] at highway U. S. 322, 1-3/4 miles northeast of Bridgeport, New Jersey [illegible] red buoy "20" and Bell C, to a point just [illegible] stack on the water front of South Chester, Pennsylvania [illegible] C. G. S. Map 295 of August 10, 1946)

New Jersey side station - 550 yards off the foot of the highway pier on the New Jersey shore; this is just in-shore of the downstream tip of Excelsior Bar, Bottom samples A1, mid-depth A2, surface A3.

New Jersey channel station - 250 yards off the foot of the highway pier on the New Jersey shore, near the middle of the New Jersey half of the channel, bottom samples A4, mid-depth A5, surface A6.

Pennsylvania channel station - 1000 yards from the foot of highway pier on the New Jersey shore and about 100 yards to the channel side of "Bell C" which is on the Pennsylvania edge of the channel, bottom samples A7, mid-depth A8, surface A9.

Pennsylvania side station - 200 yards inshore, to the Pennsylvania side, from the "Bell Buoy C" in line with the South Chester stack; this is approximately 300 yards off the Pennsylvania shore; bottom samples A10, mid-depth A11 and surface A12.

Paulsboro section B - Three stations across the Delaware River at the downstream end of Mifflin Bar Range on a north and south line from Billingsport elevated flashing light, which is 1 mile [illegible] of Paulsboro, New Jersey, and 1/2 mile south of the south bank of the river at Billingsport, through red buoy [illegible] and buoy quick flash white "1[illegible]" - [illegible] Map 295, August 10,1946.

New Jersey side station - very near to red buoy [illegible] about 200 yards off the New Jersey shore and 100 yards inshore from the south side of the channel; bottom samples [illegible] mid-depth B2, surface B3.

Channel station - at mid-channel, halfway between red buoy "M" and black, light buoy quick flash white "IF"-- this is about 500 yards north of the New Jersey shore. Bottom samples B4, mid-depth B5, surface B6.

Pennsylvania side station - 200 yards north of the quick flash white "IF" buoy; halfway between the north side of the channel and the Pennsylvania shore line off the northeast end of Mifflin Bar Dike; i. e. 200 yards off the Pennsylvania shore line structures; bottom samples B7, mid-depth B8, surface B9.

Gloucester section C. Three stations across the Delaware River at the upper end of West Horseshoe Range on a northeast to southwest line from the buildings at the railroad ferry pier on Windy Point, Pennsylvania (opposite Gloucester, New Jersey) through light buoy quick flash green "35" to red buoy N46, U.S.C. & G.S. map 295, August 10,1946.

New Jersey side station - 150 yards inshore from red buoy N46 and about 150 yards off the New Jersey shore at a point 1-1/2 miles east and north of National Park, New Jersey. Bottom samples C1, mid-depth C2, surface C3.

Channel Station - mid-channel, halfway between light buoy quick flash "35" and red buoy N 46. Bottom samples C4, mid-depth C5, surface C6.

Pennsylvania side station - off the downstream end of Horseshoe Shoal, 500 yards toward the Pennsylvania shore from light buoy quick flash green "35" on the line described for the section; bottom samples C7, mid-depth C8, surface C9.

Delaware River Bridge section E - Three stations across the Delaware River in a line 50 yards downstream at and parallel to the Delaware River Bridge between Philadelphia and Camden, New Jersey. The Pennsylvania end of this line was at Pier 9, Philadelphia.

New Jersey side station - about 150 yards off the New Jersey shore; bottom samples E1, mid-depth E2, surface E3.

Channel station - at midchannel; bottom sample E4, mid-depth E5, surface E6.

Pennsylvania side station - a few yards off distal end of Pier No. 9; bottom samples E7, mid-depth E8, surface E9.

Riverton section F - Three stations across the Delaware River on a north northwest to south southeast line passing through red buoy N "44", which lies 100 yards off the Riverton, New Jersey, waterfront midway between the 2 second occ. ev. light on the New Jersey shore of the Tacony channel and the 6 second occ. ev. light on the New Jersey shore of the Riverton channel, and continues through the black buoy C3 to an elevated tank, in North Tacony, Pennsylvania, between a tank and a stack to the northeast and a cup tank to the southwest—See U.S.C. & G.S.Map 296, August 10, 1946.

New Jersey side station - 50 yards inshore from the red buoy "N4A"; bottom samples F1, mid-depth F2, surface F3.

Channel station - 150 yards from buoy N4A and 50 yards from black buoy C3—that is the mid-channel lies a little nearer the black buoy; bottom samples F4, mid-depth F5, surface F6.

Pennsylvania side station - 300 yards to the Pennsylvania side of the black buoy C3. This was little more than 50 yards off the Pennsylvania shore line; bottom samples F7, mid-depth F8, surface F9.

Beverly section G - A single mid-channel station in the Delaware River near the middle of the Enterprise Range 150 yards off the Pennsylvania shore line at Occ. ev. 2 second light which is a mile northeast of Andalusia, Pennsylvania, and across the river and 3/4 of a mile southwest of Beverly, New Jersey. This station is 75 yards toward the Pennsylvania shore from red buoy N "16A".

Channel station - Bottom samples G1, mid-depth G2, surface G3, U.S.C. & G.S.Map 296, August 10, 1946.

Burlington section H - A single mid-channel station in the Delaware River at the junction of the Edgewater channel and the Delvin Channel midway between red buoy N"18C" and black buoy C"17D". This area is about 1 mile east of College Point, Pennsylvania and 1 mile west of Burlington, New Jersey.

Channel station - Bottom samples H1, mid-depth H2, surface H3, U.S.C. & G.S.Map 296, August 10, 1946.

Delaware City section I - Three stations across the Delaware River in the Finns Point Range, on an east and west line from the mouth of the Delaware City Branch Canal in Delaware to a point midway between the elevated lights at the mouth of Salem Cove in New Jersey. This line passes just north of red buoys N"4N" and N2 and just south of black buoys C5N and lighted black buoy flash green "1." - U.S.C. & G.S.Map 294, August 3, 1946.

New Jersey side station - 400 yards east of red buoy N"4N" This is - 4000 yards off the New Jersey shore at the mouth of Salem River; bottom samples I1, mid-depth I2, surface I3.

Channel station - halfway between red buoy N"4N" and black buoy C5N - in middle of the main channel 2900 yards off the mouth of the canal at Delaware City, Del; bottom samples I4, mid-depth I5, surface I6.

Delaware side station - 1000 yards west of black buoy C5N and 300 yards east of red buoy N2, that is 150 yards east of Bulkhead Shoal Channel which serves Delaware City, Del., and in the water which shallows toward the east and north to Pea Patch Island 3/5 mile upstream; bottom samples I 7, depth I 8, and surface I 9.

Pennsville section J - Three stations across the Delaware River in the Deepwater Point Range on a northwest southeast line through red light buoy, flash red "6A" and black buoy C29. The New Jersey end of this line passes through Pennsville, New Jersey; on the west side it passes midway between New Castle, Delaware, and Pigeon Point which is one mile south of Christina River. U.S.C. & G.S. Map 294, August 3, 1946.

New Jersey side station 200 yards nearer the New Jersey shore than red buoy light Fl R"6A"; about 600 yards off the New Jersey shore nearest Pennsville, N. J.; bottom samples Ji, mid-depth J2, surface J3.

Channel station - mid-channel equidistant, about 400 yards each way from the aforesaid buoys. Bottom sample J4, mid-depth J5, surface J6.

Delaware side station - 200 yards NW of black buoy C29; i.e. about 800 yards off the Delaware shore line and on the deep water edge of the New Castle Flats. Bottom samples J7, mid-depth J8, surface J9.

Bordentown section L - A single channel station in the Delaware River at the junction of Bordentown range below with the Rock Island Range upstream on a line between red buoy N8 and black buoy C7. This line is just north of the point at which the backwater of Duck Creek enters river 1 mile north of Bordentown, N.J.

Channel station - a few yards to the channel side of black buoy C7; surface samples L1. U.S.C. & G.S.Map 296, August 10, 1946.

Lambertville section M a mid-channel station in the Delaware River where highway Pa. 263 crosses the river at Centerbridge Pa., 3 miles north of Lambertville, N. J.

Channel station - at mid-depth M1.

Easton section N - a Delaware River station 10 feet off the Pennsylvania shore at a point opposite the locks in the Lehigh-Delaware Canal, about 1 mile below the mouth of the Lehigh River and Easton, Pa.

Pennsylvania side station - surface sample N1..

Port Jervis, New York section P - Delaware River one mile above Port Jervis, N.Y. on highway N. Y. 42, stream 200 yards wide; sample at mid-depth P 1.

Penrose Ferry Bridge section D - Two stations across the Schuylkill River in a line crossing the stream at right angles to the banks, 200 yards below the Penrose Ferry Bridge in Philadelphia.

North channel station - Bottom samples D 1, mid-depth D 2. surface D 3.

South channel station - Bottom sample D 4, mid-depth D 5, Surface D 6.

Conshohocken station K - in the Schuylkill River 6 feet off the north shore, 300 yards upstream from the bridge on highway Pa. 320 between Conshohocken and West Conshohocken, Pa.; a surface sample K1

Hamburg station Q - in the Schuylkill River, a mid-channel station taken from the bridge on highway U. S. 22 at the western edge of Hamburg, Pa.; a surface sample Q 1.

Broadhead Creek one mile above its mouth, in the Delaware River, along highway Pa. 402 near Stroudsburg, Pa. Sample taken off the right bank at a point where the stream was narrowed at a sharp bend. Stream bed rock, current rapid and water very clear.

Lehigh River at Easton, Pa. sample off the north bank of the Lehigh River 200 yards downstream from the bridge on highway U. S. 611. This is about 200 yards above the mouth of the Lehigh in the Delaware River. The current was sluggish and a surface drain ditch carrying some oil from a garage entered the river between the bridge and the point of sampling. A surface sample Q 1.

Hudson River at Verplanck, N. Y., 3 miles downstream from Peekskill, N.Y. on highway N.Y. 210. A series of channel, mid-depth samples taken 200 yards off the Sinclair & Amco Oil Storage Co. dock. The river at this point is about 1 mile wide, 40 to 65 feet deep to within 75 feet of the banks on either side.

Figure 1. Mid-channel mid-depth dissolved oxygen profile
Second week of September, 1946

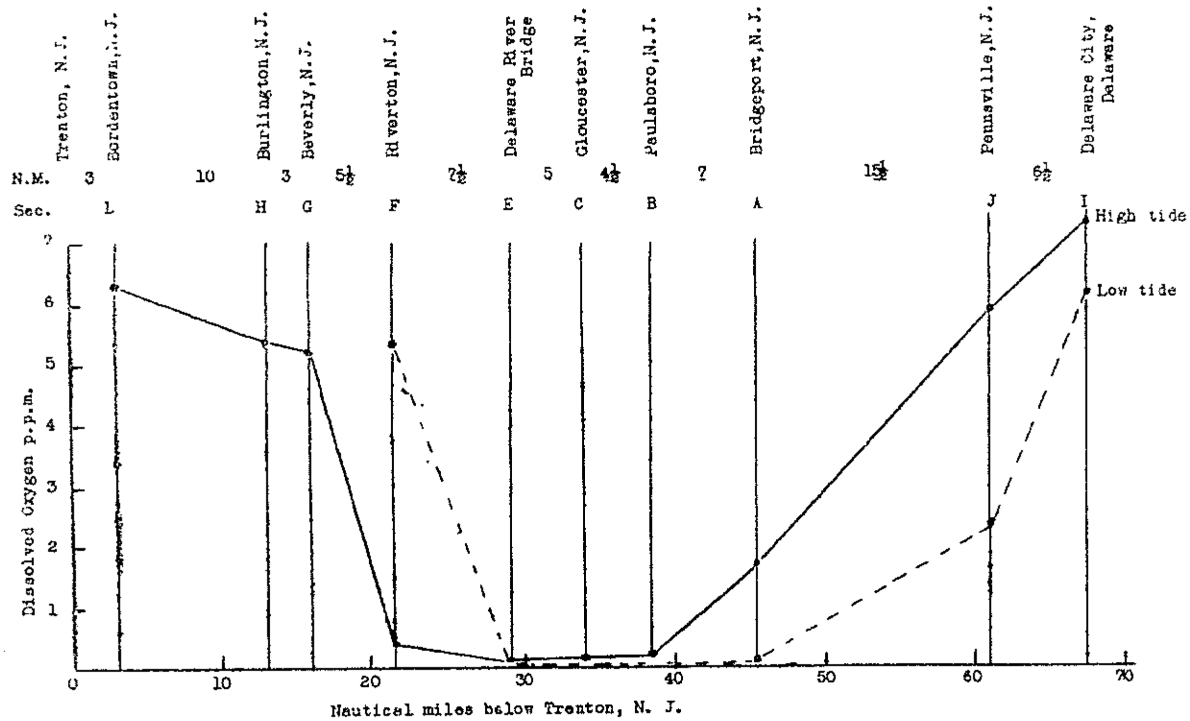
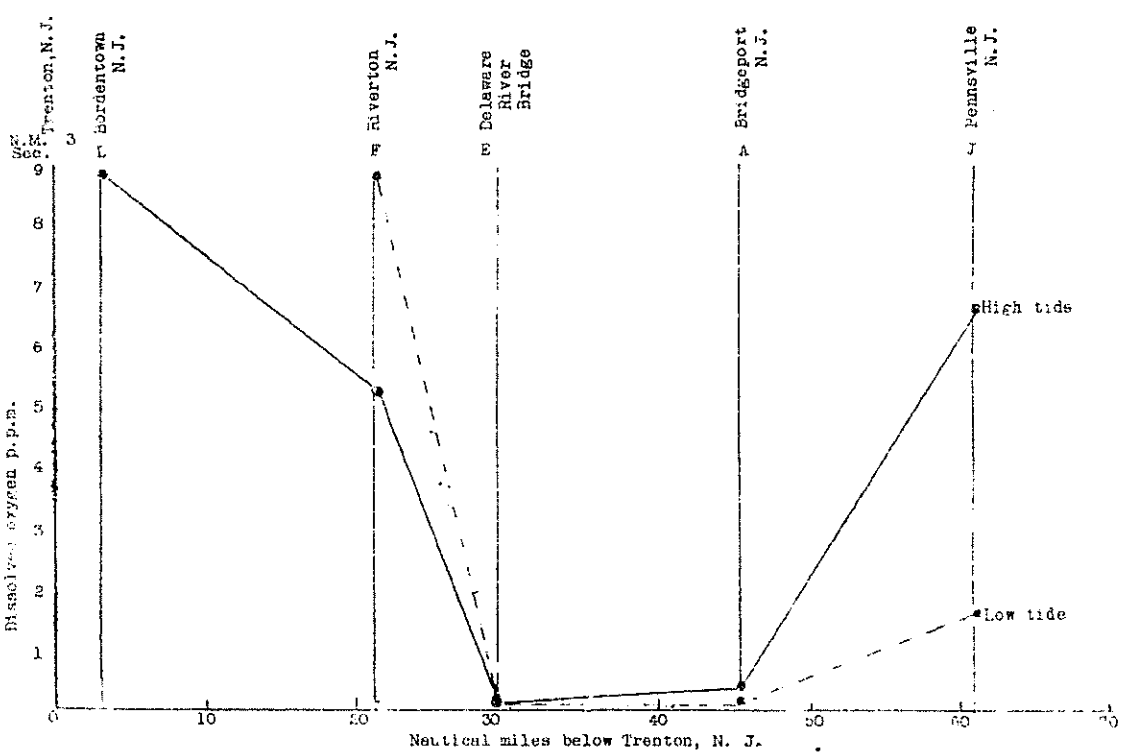


Figure 2. Mid-channel mid-depth dissolved oxygen profile
Third week of October, 1946



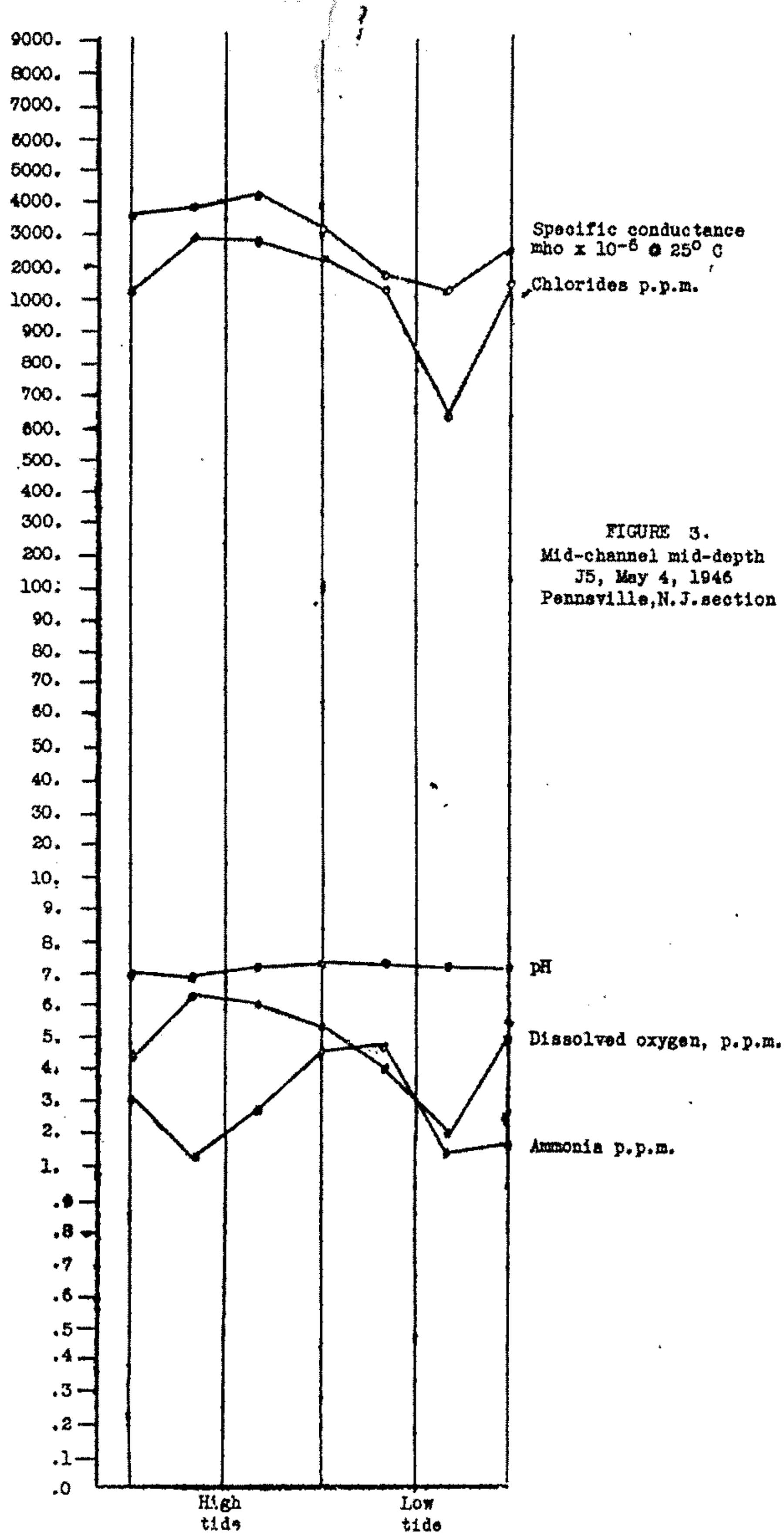


FIGURE 3.
Mid-channel mid-depth
J5, May 4, 1946
Pennsville, N.J. section

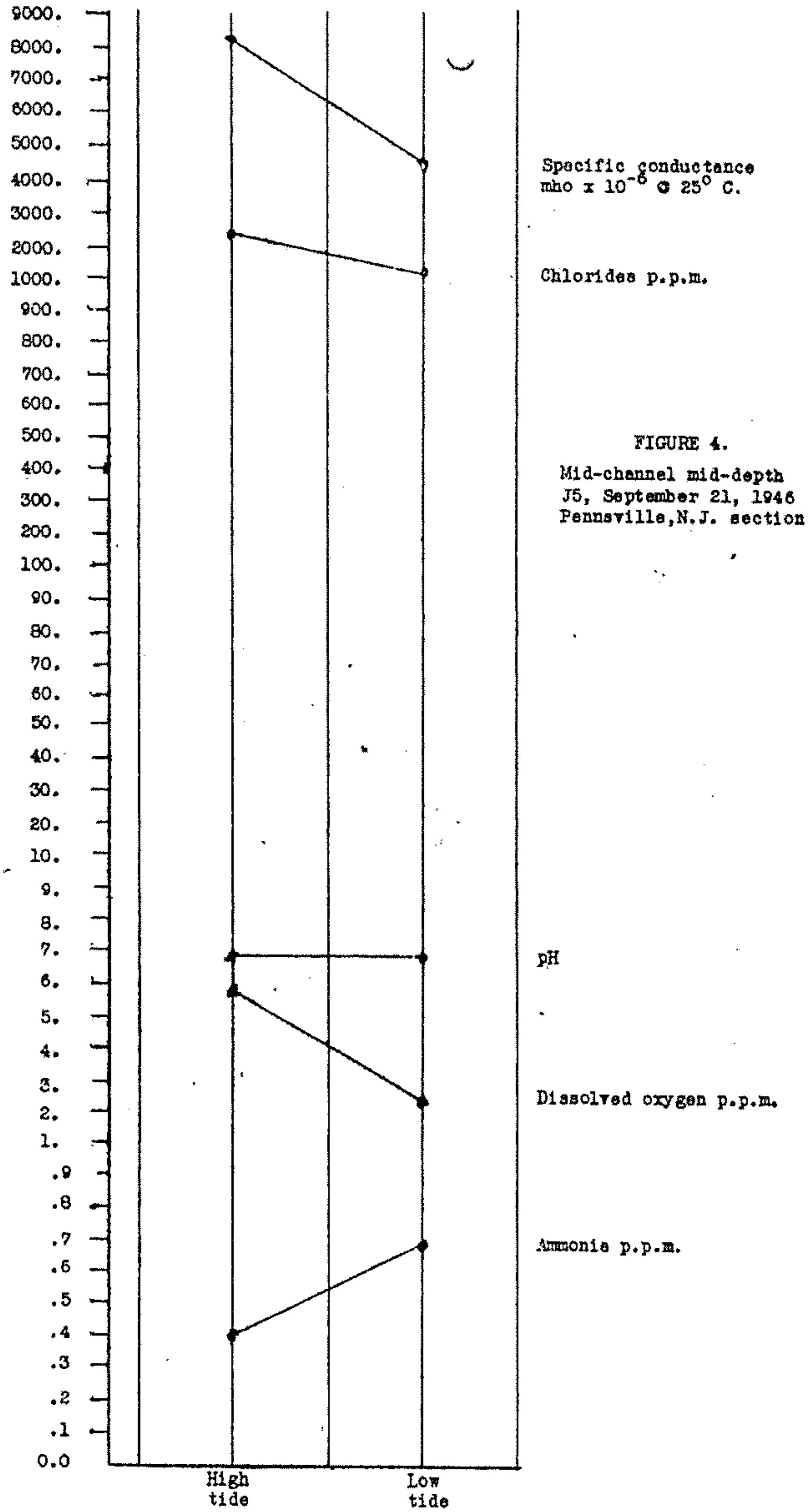


FIGURE 4.

Mid-channel mid-depth
J5, September 21, 1946
Pennsville, N.J. section

FIGURE 5.

Mid-channel mid-depth
J5, October 19, 1946
Pennsville, N. J. section

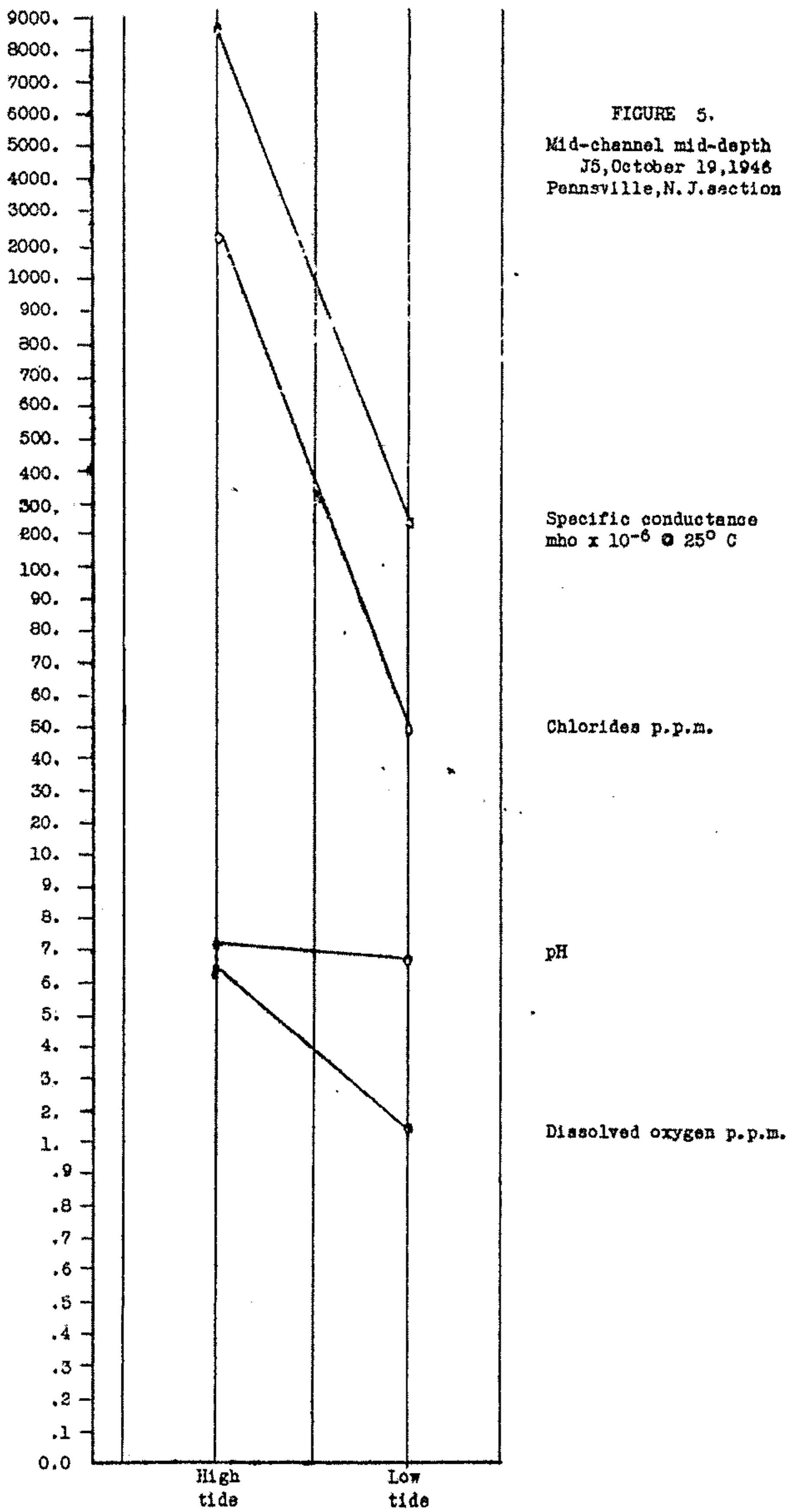
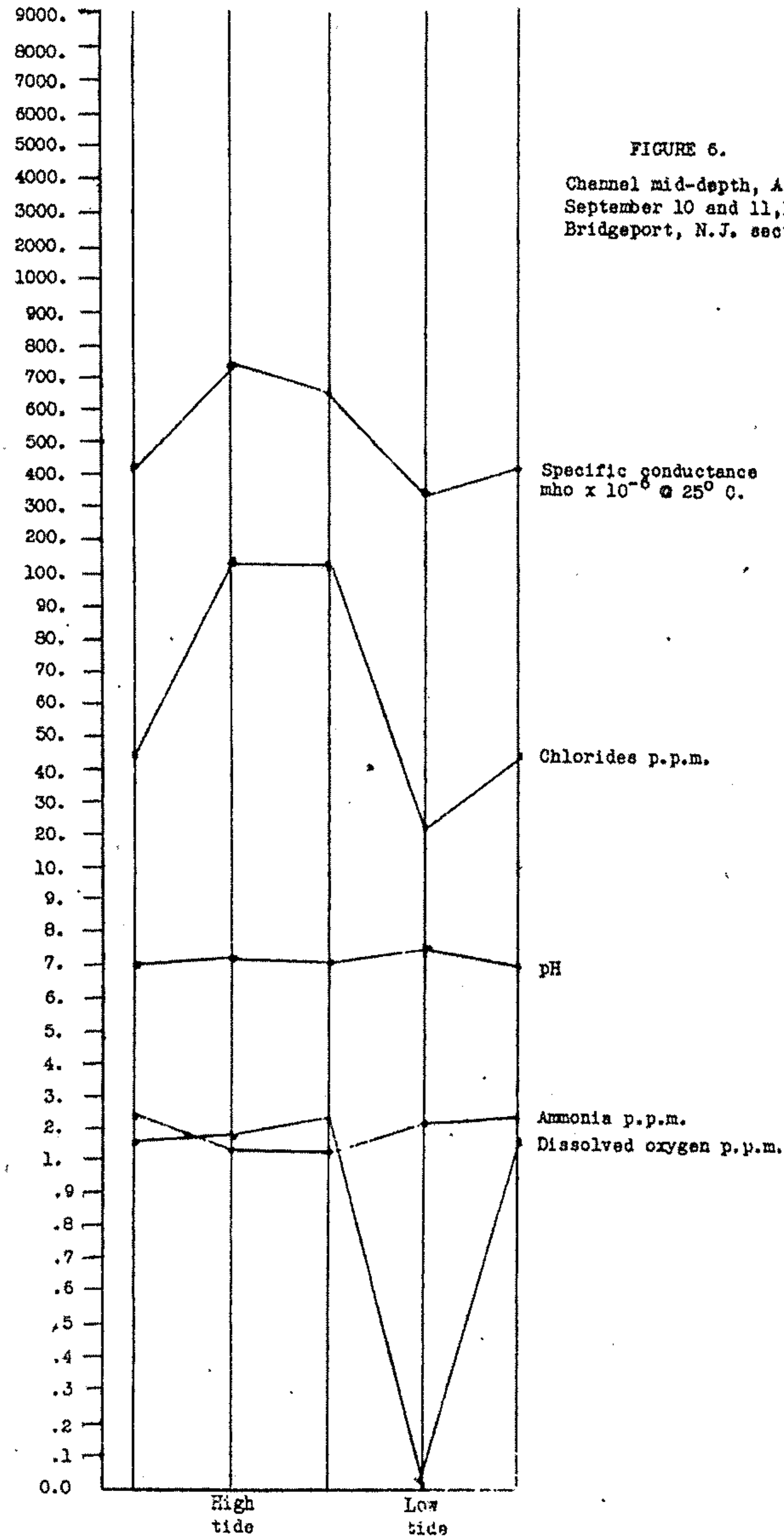


FIGURE 6.

Channel mid-depth, A 8
September 10 and 11, 1946
Bridgeport, N.J. section



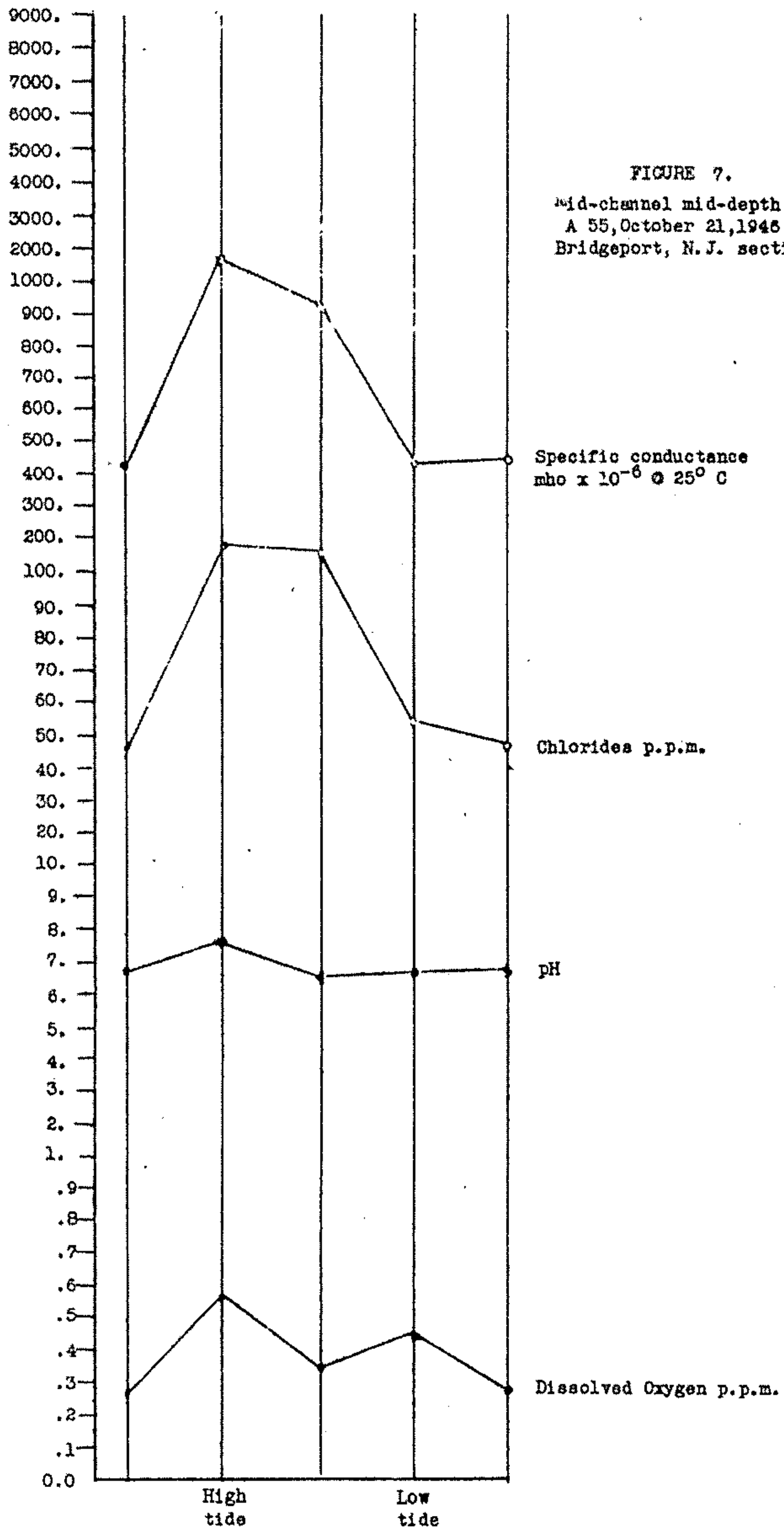


FIGURE 7.
Mid-channel mid-depth
A 55, October 21, 1946
Bridgeport, N.J. section

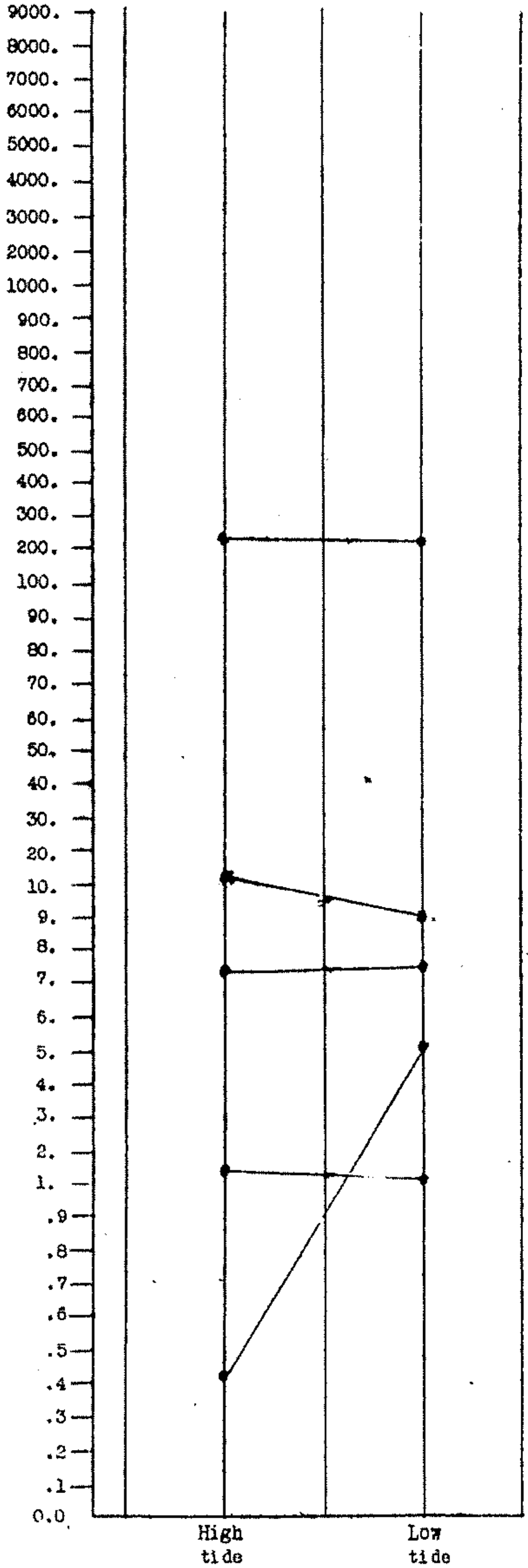
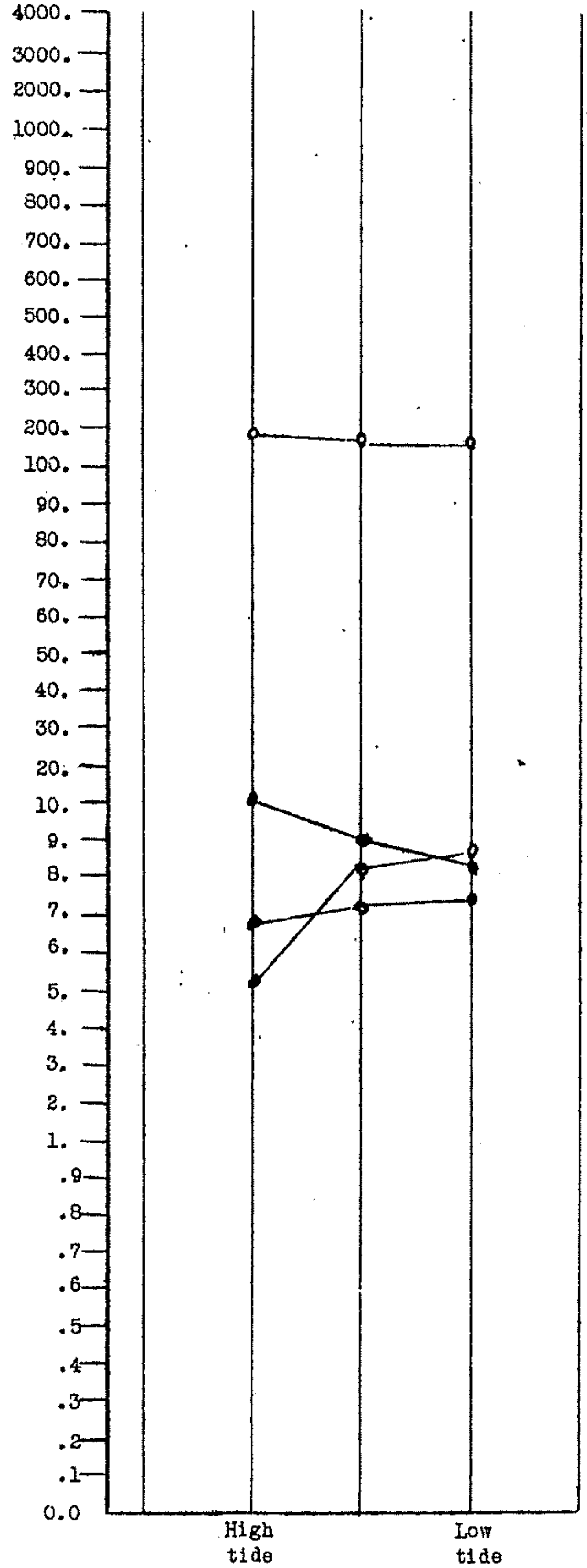


FIGURE 8.
Mid-channel, mid-depth
F5, September 17, 1946
Riverton, N.J. section



Specific conductance
mho x 10^{-6} @ 25° C

FIGURE 9.
Mid-channel, mid-depth
F5, October 22, 1946
Riverton, N. J. section

Dissolved oxygen p.p.m.
Chlorides p.p.m.
pH

FIGURE 10.
Location of Major Stations
on Hudson and Delaware Rivers

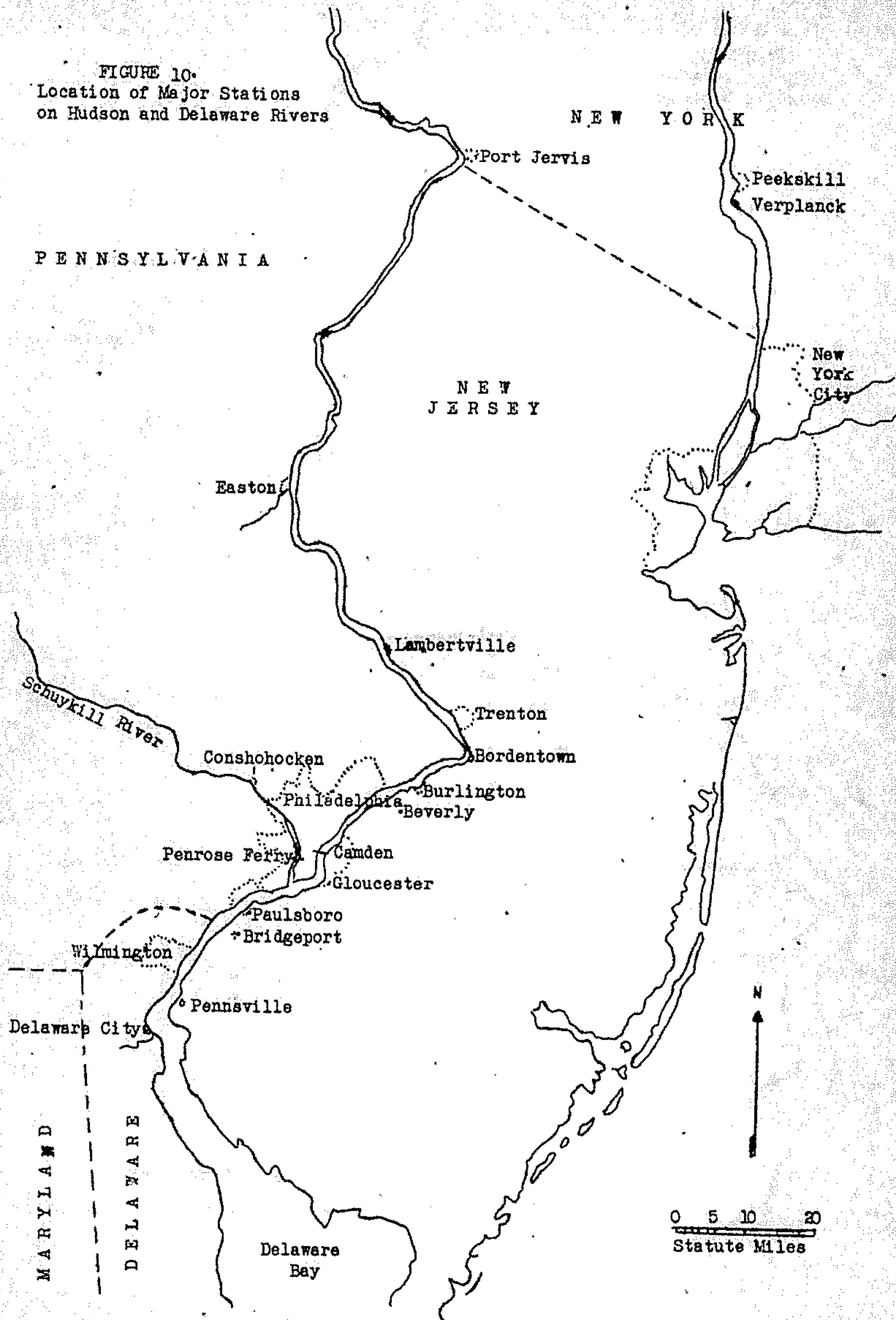


FIGURE 11
Location of Major
Sampling Sections

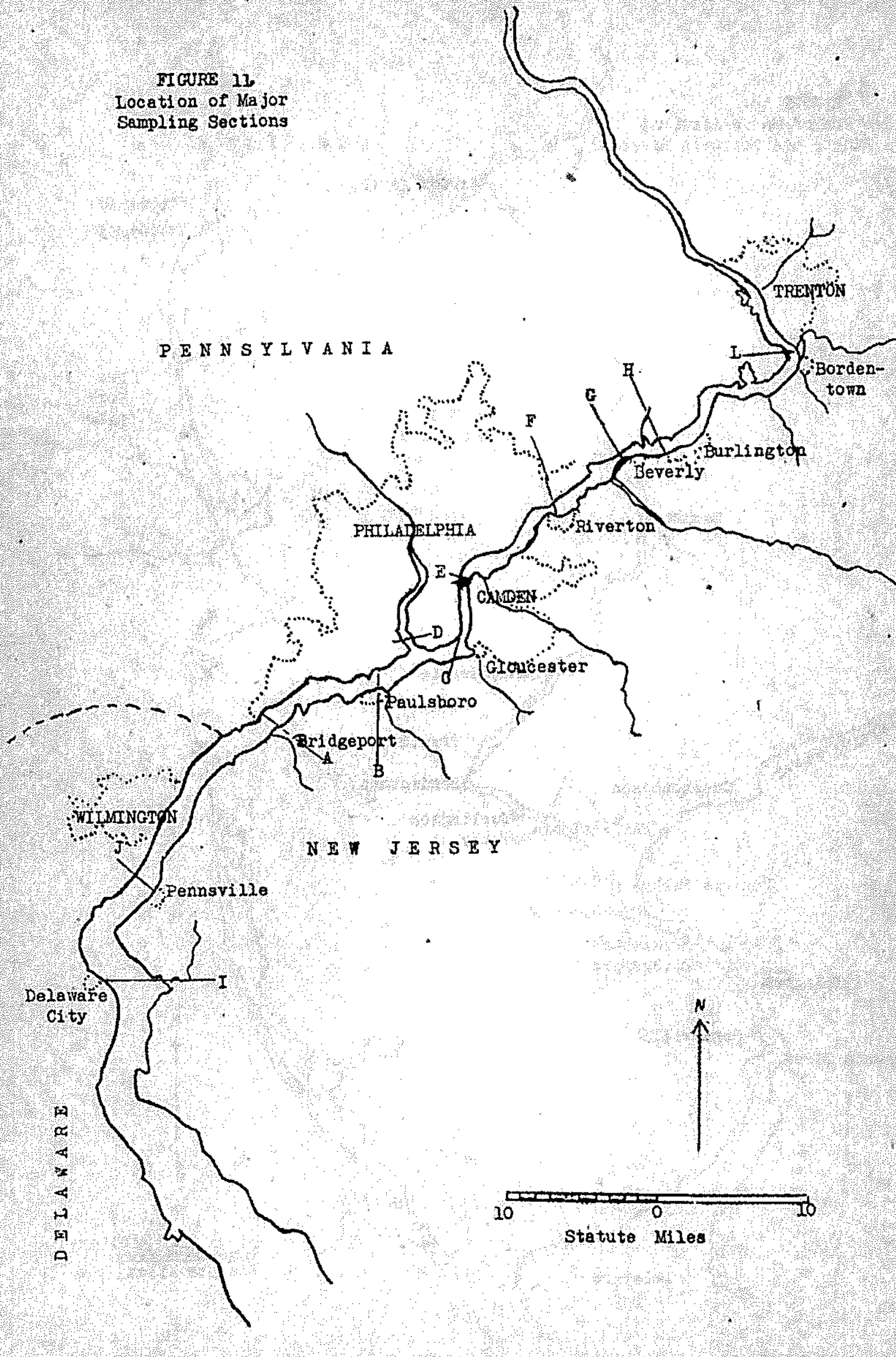


Table 1.

Tide cycle study of water characteristics of Delaware River off Pennsville, New Jersey, May 4, 1946
Mid-channel, mid-depth samples~~*~~

Time	Tide[a]	Temperature centigrade	Dissolved oxygen p.p.m.	Oxygen consumed from 10 x $KMnO_4$ p.p.m.		Specific Conductance mho x 10^{-6} at 25° C	pH	Carbonates as CO_3 p.p.m.	Ammonia p.p.m.	Sulfates as SO_4 p.p.m.	Chlorides as Cl p.p.m.	Calcium p.p.m.	Organic matter p.p.m.
				Whole	Filtered								
7:00 A.M.		14.0	5.3	28	13	3,090	7.3	30	4.8	149	2,128	34	92
9:00 A.M.	Dead low	14.0	4.0	26	11	1,610	7.2	30	4.8	106	1,132	29	64
11:00 A.M.		14.0	2.0	26	11	1,045	7.2	33	1.2	87	636	23	70
1:00 P.M.		13.8	5.0	21	14	2,430	7.1	30	1.8	147	1,532	30	86
3:00 P.M.	Dead high	14.0	6.1	27	26	3,910	6.9	30	1.2	198	2,948	40	96
5:00 P.M.		13.8	6.0	28	22	4,060	7.1	30	2.7	198	2,980	39	180
7:00 P.M.		13.6	4.5	29	18	3,600	7.0	29	3.0	160	1,010	36	100

(a) Dead low and dead high indicate no current at point of sampling. The time reading may not be exactly that given in the tide tables for May 4, 1946.

~~* Section J on maps, position designation J 5.~~

Table 2.

Water quality data, Delaware River system stations, April 27 - May 4, incl. 1946

Station[a]	Temperature centigrade	Dissolved oxygen p.p.m.	Oxygen consumed from 10 x $KMnO_4$ p.p.m.		Specific conductance mho x 10^{-6} at 25° C	pH	Carbonates as CO_3 p.p.m.	Ammonia p.p.m.	Chlorides as Cl p.p.m.	Sulfates as SO_4 p.p.m.	Calcium p.p.m.	Organic matter p.p.m.
			Whole	Filtered								
Delaware River Port Jervis, N. Y.	8.0	11.6	4	1	68	7.4	12	1.5	12	0	5	trace
Broadhead Creek near Stroudsburg, Pa.	8.5	11.8	4	1	71	8.2	17	0.0	10	0	3	trace
Schuykill River, Philadelphia, Pa. (b)	14.0	0.4	22	7	453	7.1	67	2.3	58	80	31	74
Delaware River, Pennsville, N. J. (c)	14.0	2.0	26	1	1045	7.2	33	1.2	636	87	23	70
Delaware River Pennsville, N.J.	13.8	6.0	28	22	4060	7.1	30	2.7	2980	198	39	100

(a) All stations are mid-channel and midway between surface and bottom.

(b) Dead low tide.

(c) Dead high tide.

Tablo 3.

Tide cycle study of water characteristics of Hudson River off Verplanck, New York, April 30, 1946
Mid-channel, mid-depth samples -- Temperatures 10.0-11.5° C

Time	Tide[a]	Temperature centigrade	Dissolved oxygen p.p.m.	Oxygen consumed from 10 x $KMnO_4$ p.p.m. Whole	Oxygen consumed from 10 x $KMnO_4$ p.p.m. Filtered	Specific conductance mho x 10^{-6} at 25° C	pH	Carbonates as CO_3 p.p.m.	Ammonia p.p.m.	Sulfates as SO_4 p.p.m.	Chlorides as Cl p.p.m.	Calcium p.p.m.	Organic matter p.p.m.
6:00 A.M.	Dead low	10.0	8.9	32	6	4,560	7.4	53	1.8	176	3,816	41	140
8:00 A.M.		10.0	9.0	27	7	5,390	7.6	51	1.3	202	4,436	48	145
10:00 A.M.		11.3	8.7	29	12	5,770	7.3	51	1.5	201	4,140	45	148
12:00 Noon	Dead high	11.5	8.7	36	12	6,850	7.3	53	3.6	241	5,310	53	160
2:00 P.M.		10.5	8.7	52	12	6,780	7.3	52	2.4	232	5,250	54	168
4:00 P.M.		10.2	8.7	27	12	6,140	7.6	52	2.5	219	4,770	51	160
6:00 A.M.	Dead low	10.4	8.7	14	11	5,620	7.7	51	1.8	165	3,800	42	155

[a] Dead low and dead high indicate no current at sampling point and may not agree exactly with low and high as given in the tide tables for April 30, 1946.

Table 4

WATER CHARACTERISTICS OF THE DELAWARE RIVER
BRIDGEPORT, NEW JERSEY SECTION*, TIDE HALF IN**
September 10, 1946. Sampling started at 10:00 AM

Station	Sample position	Position designation	Temperature degrees Centigrade	Dissolved oxygen p.p.m.	Oxygen consumed from $KMnO_4$ p.p.m.	Specific conductance mho x 10^{-6} @ 25° C.	pH	Total carbonates p.p.m.	Total ammonia p.p.m.	Total phosphates p.p.m.	Total chlorides p.p.m.	Total sulfates p.p.m.
New Jersey Side	Bottom	A 1	24.0	1.96	18.2	435	7.0					
	Mid-depth	A 2	24.0	1.93	10.1	413	7.1	29	2.30	0.135	56	57
	Surface	A 3	24.5	1.88	9.3	435	7.0					
New Jersey Channel	Bottom	A 4	24.0	1.12	21.2	396	7.1					
	Mid-depth	A 5	24.0	2.15	10.0	399	7.1	29	2.44	0.133	46	50
	Surface	A 6	24.5	1.50	8.1	407	7.0					
Pennsylvania Channel	Bottom	A 7	24.0	0.62	14.5	391	7.1					
	Mid-depth	A 8	24.2	1.74	11.9	411	7.0	29	2.48	0.147	43	43
	Surface	A 9	24.5	1.14	11.4	393	6.9					
Pennsylvania Side	Bottom	A10	24.0	0.31	12.7	468	7.0					
	Mid-depth	A11	24.5	0.54	10.8	503	7.0	31	2.30	0.220	89	52
	Surface	A12	24.9	0.93	7.5	517	7.0					

* Section A on maps

** High tide at 11:45 AM

Table 5

WATER CHARACTERISTICS OF THE DELAWARE RIVER
BRIDGEPORT, NEW JERSEY SECTION*, TIDE PARTLY OUT**
September 10, 1946. Sampling started [illegible] 1:45 PM

Station	Sample position	Position designation	Temperature degrees Centigrade	Dissolved oxygen p.p.m.	Oxygen consumed from $KMnO_4$ p.p.m.	Specific conductance mho x 10^{-6} at 25^{0} C.	pH	Total carbonates p.p.m.	Total ammonia p.p.m.	Total phosphates p.p.m.	Total chlorides p.p.m.	Total sulfates p.p.m.
New Jersey Side	Bottom	A 1	24.0	2.00	11.4	723	7.1					
	Mid-depth	A 2	24.1	2.14	6.9	707	7.2	29	1.06	0.130	122	63
	Surface	A 3	24.8	2.60	6.4	654	7.0					
New Jersey Channel	Bottom	A 4	24.0	1.60	8.1	729	7.1					
	Mid-depth	A 5	24.0	1.88	6.3	701	7.0	32	1.42	0.095	120	58
	Surface	A 6	24.5	2.62	5.1	622	7.0					
Pennsylvania Channel	Bottom	A 7	24.0	1.60	16.2	557	7.0					
	Mid-depth	A 8	24.0	2.30	7.8	660	7.0	29	1.24	0.138	108	61
	Surface	A 9	24.5	2.28	6.9	688	7.0					
Pennsylvania Side	Bottom	A10	24.0	0.75	20.9	484	7.0					
	Mid-depth	A11	24.5	1.00	6.1	508	7.0	31	2.36	0.133	65	46
	Surface	A12	25.0	0.84	7.4	547	7.0					

* Section A on maps

** High tide at 11:45 AM

Table 6.

WATER CHARACTERISTICS OF THE DELAWARE RIVER
BRIDGEPORT, NEW JERSEY SECTION*, LOW TIDE**
September 11, 1946. Sampling started at 8:10 AM

Station	Sample position	Position designation	Temperature degrees Centigrade	Dissolved oxygen p.p.m.	Oxygen consumed from $KMnO_4$ p.p.m.	Specific conductance mho x 10^{-6} @ 25° C.	pH	Total carbonates p.p.m.	Total ammonia p.p.m.	Total phosphates p.p.m.	Total chlorides p.p.m.	Total sulfates p.p.m.
New Jersey Side	Bottom	A 1	24.0	0.30	2.9	364	7.2					
	Mid-depth	A 2	24.0	0.77	0.6	342	7.4	39	2.46	0.115	29	38
	Surface	A 3	24.5	0.77	5.2	287	7.3					
New Jersey Channel	Bottom	A 4	24.0	0.00	5.2	336	7.3					
	Mid-depth	A 5	24.0	0.00	2.3	327	7.3	30	2.60	0.103	20	35
	Surface	A 6	24.0	0.17	2.9	320	7.4					
Pennsylvania Channel	Bottom	A 7	24.5	0.00	12.2	329	7.3					
	Mid-depth	A 8	24.0	0.00	4.0	333	7.3	35	2.20	0.150	22	34
	Surface	A 9	24.0	0.21	4.6	334	7.5					
Pennsylvania Side	Bottom	A10	24.5	0.00	2.9	326	7.4					
	Mid-depth	A11	24.5	0.10	5.8	323	7.3	35	2.42	0.138	25	37
	Surface	A12	24.0	0.07	5.8	372	7.4					

* Section A on maps.
** Low tide at 7:20 AM

Table 7.

**WATER CHARACTERISTICS OF THE DELAWARE RIVER
BRIDGEPORT, NEW JERSEY SECTION*, HIGH TIDE**
September 11, 1946. Sampling started at 1:30 PM**

Station	Sample position	Position designation	Temperature degrees Centigrade	Dissolved oxygen p.p.m.	Oxygen consumed from $KMnO_4$ p.p.m.	Specific conductance mho x 10^{-6} @ 25° C.	pH	Total carbonates p.p.m.	Total ammonia p.p.m.	Total phosphates p.p.m.	Total chlorides p.p.m.	Total sulfates p.p.m.
New Jersey Side	Bottom	A 1	24.0	2.98	8.7	784	7.28					
	Mid-depth	A 2	24.0	2.60	6.4	776	7.28	25	1.94	0.115	143	65
	Surface	A 3	24.5	2.82	9.8	757	7.30					
New Jersey Channel	Bottom	A 4	24.0	1.54	7.5	657	7.31					
	Mid-depth	A 5	24.0	2.10	6.4	680	7.18	28	1.40	0.103	120	68
	Surface	A 6	24.5	2.06	4.0	576	7.15					
Pennsylvania Channel	Bottom	A 7	24.0	1.68	7.5	740	7.17					
	Mid-depth	A 8	24.0	1.72	5.2	755	7.05	30	1.30	1.103	141	66
	Surface	A 9	24.5	1.85	2.9	684	7.15					
Pennsylvania Side	Bottom	A10	24.0	1.14	4.0	790	7.12					
	Mid-depth	A11	24.0	0.79	1.7	594	7.15	25	1.90	0.145	93	51
	Surface	A12	24.5	1.18	4.0	597	7.20					

* Section A on maps
** High tide at 12:28 PM

Table 8

WATER CHARACTERISTICS OF THE DELAWARE RIVER
PAULSBORO, NEW JERSEY SECTION*, LOW TIDE**
September 12, 1946. Sampling started at 8:45 AM

Station	Sample position	Position designation	Temperature degrees Centigrade	Dissolved oxygen p.p.m.	Oxygen consumed from $KMnO_4$ p.p.m.	Specific conductance mho x 10^{-6} @ 25° C.	pH	Total carbonates p.p.m.	Total ammonia p.p.m.	Total phosphates p.p.m.	Total chlorides p.p.m.	Total sulfates p.p.m.
New Jersey Side	Bottom	B 1	23.5	0.00	9.8	248	7.2					
	Mid-depth	B 2	23.5	0.00	8.7	234	7.2	30	3.10	0.126	16	2
	Surface	B 3	23.5	0.05	7.5	296	7.2					
Channel	Bottom	B 4	24.0	0.00	12.2	265	7.2					
	Mid-depth	B 5	24.0	0.00	15.7	225	6.8	28	2.16	0.110	16	8
	Surface	B 6	23.5	0.00	7.5	222	6.5					
Pennsylvania Side	Bottom	B 7	23.5	0.00	7.5	298	6.6					
	Mid-depth	B 8	23.5	0.00	12.2	297	7.2	33	2.57	0.112	16	7
	Surface	B 9	24.0	0.00	8.7	268	7.3					

* Section B on maps.

** Low tide at 8:32 AM

Table 9.

WATER CHARACTERISTICS OF THE DELAWARE RIVER
PAULSBORO, NEW JERSEY SECTION*, HIGH TIDE**
September 12, 1946. Sampling started at 2:00 PM

Station	Sample position	Position designation	Temperature degrees Centigrade	Dissolved oxygen p.p.m.	Oxygen consumed from $KMnO_4$ p.p.m.	Specific conductance mho x 10^{-6} @ 25° C.	pH	Total carbonates p.p.m.	Total ammonia p.p.m.	Total phosphates p.p.m.	Total chlorides p.p.m.	Total sulfates p.p.m.
New Jersey Side	Bottom	B 1	24.0	0.00	7.5	293	7.6					
	Mid-depth	B 2	24.0	0.00	8.7	294	7.3	29	2.30	0.138	19	3
	Surface	B 3	24.5	0.32	9.8	246	7.3					
Channel	Bottom	B 4	24.0	0.14	11.0	318	7.3					
	Mid-depth	B 5	24.0	0.19	15.7	308	7.3	29	2.40	0.112	24	18
	Surface	B 6	24.5	0.27	8.7	305	7.3					
Pennsylvania Side	Bottom	B 7	24.0	0.00	5.2	295	7.3					
	Mid-depth	B 8	24.0	0.00	12.2	306	7.3	29	2.32	0.145	19	16
	Surface	B 9	24.5	0.00	5.2	296	7.2					

* Section B on maps
** High tide at 1:35 PM

Table 10

WATER CHARACTERISTICS OF THE DELAWARE RIVER
GLOUCESTER, NEW JERSEY SECTION*, LOW TIDE**
September 13, 1946. Sampling started at 10:00 AM

Station	Sample position	Position designation	Temperature degrees Centigrade	Dissolved oxygen p.p.m.	Oxygen consumed from $KMnO_4$ p.p.m.	Specific conductance mho x 10^{-6} @ 25° C.	pH	Total carbonates p.p.m.	Total ammonia p.p.m.	Total phosphates p.p.m.	Total chlorides p.p.m.	Total sulfates p.p.m.
New Jersey Side	Bottom	C 1	23.0	0.00	2.4	291	7.5					
	Mid-depth	C 2	23.0	0.00	9.3	288	7.4	31	1.40	0.176	16	16
	Surface	C 3	23.0	0.00	9.8	272	7.4					
Channel	Bottom	C 4	23.3	0.00	13.3	282	7.3					
	Mid-depth	C 5	23.5	0.00	13.3	291	7.2	32	1.20	0.170	16	9
	Surface	C 6	23.0	0.00	11.0	294	7.1					
Pennsylvania Side	Bottom	C 7	23.5	0.00	12.2	301	7.5					
	Mid-depth	C 8	23.5	0.00	11.0	296	7.4	31	2.16	0.220	16	5
	Surface	C 9	23.5	0.00	8.7	259	7.3					

* Section C on maps

** Low tide at 9:44 AM

Table 11

WATER CHARACTERISTICS OF THE DELAWARE RIVER
GLOUCESTER, NEW JERSEY SECTION*, HIGH TIDE**
September 13, 1946. Sampling started at 3:00 PM

Station	Sample position	Position designation	Temperature degrees Centigrade	Dissolved oxygen p.p.m.	Oxygen consumed from $KMnO_4$ p.p.m.	Specific conductance mho x 10^{-6} @ 25° C.	pH	Total carbonates p.p.m.	Total ammonia p.p.m.	Total phosphates p.p.m.	Total chlorides p.p.m.	Total sulfates p.p.m.
New Jersey Side	Bottom	C 1	23.0	0.27	7.5	286	6.6					
	Mid-depth	C 2	22.5	0.26	5.8	241	6.8	30	2.06	0.102	16	3
	Surface	C 3	23.0	0.55	4.6	269	6.8					
Channel	Bottom	C 4	23.0	0.00	9.1	314	7.2					
	Mid-depth	C 5	23.0	0.08	7.2	317	6.9	30	2.70	0.110	17	11
	Surface	C 6	23.0	0.31	5.2	259	7.2					
Pennsylvania Side	Bottom	C 7	23.0	0.08	8.3	314	7.2					
	Mid-depth	C 8	23.0	0.10	7.9	308	7.3	31	2.64	0.145	18	13
	Surface	C 9	23.0	0.00	6.4	260	7.2					

* Section C on maps
** High tide at 2:53 PM

Table 12

WATER CHARACTERISTICS OF THE SCHUYKILL AND LEHIGH RIVERS
September 14-22, 1946

Station	Sample position	Position designation	Temperature degrees Centigrade	Dissolved oxygen p.p.m.	Oxygen consumed from $KMnO_4$ p.p.m.	Specific conductance mho x 10^{-6} @ 25° C.	pH	Total carbonates p.p.m.	Total ammonia p.p.m.	Total phosphates p.p.m.	Total chlorides p.p.m.	Total sulfates p.p.m.
SCHUYKILL												
Philadelphia												
No. Channel	Bottom	D 1	25.5	0.00	13.3	482	7.2					
(Low Tide)	Mid-depth	D 2	25.5	0.00	17.9	472	7.1	49	2.75	0.082	28	92
	Surface	D 3	26.0	0.00	14.5	474	7.1					
So. Channel	Bottom	D 4	25.5	0.00	13.9	421	7.3					
(Low Tide)	Mid-depth	D 5	25.5	0.00	15.7	471	7.2	35	2.75	0.124	29	11
	Surface	D 6	26.0	0.00	33.0	572	7.2					
Conshohocken	Surface	K 1	25.0	4.87	11.0	520	8.0	26	0.78	0.286	13	130
Hamburg	Surface	Q 1	22.0	4.30	--	620	4.7	4	0.81	0.005	0	301
LEHIGH												
No. Easton	Surface	O 1	22.0	5.79	3.7	313	7.1	29	1.10	0.077	9	9

Shown on maps as Sections D, K, Q and O.

Table 13

WATER CHARACTERISTICS OF THE DELAWARE RIVER
DELAWARE RIVER BRIDGE SECTION*, LOW TIDE**
September 15, 1946. Sampling started at 11:30 AM

Station	Sample position	Position designation	Temperature degrees Centigrade	Dissolved oxygen p.p.m.	Oxygen consumed from $KMnO_4$ p.p.m.	Specific conductance mho x 10^{-6} @ 25° C.	pH	Total carbonates p.p.m.	Total ammonia p.p.m.	Total phosphates p.p.m.	Total chlorides p.p.m.	Total sulfates p.p.m.
New Jersey Side	Bottom	E 1	22.0	0.00	8.7	296	7.3					
	Mid-depth	E 2	22.0	0.00	4.0	237	6.4	33	2.74	0.200	15	0
	Surface	E 3	22.5	0.00	7.5	300	7.4					
Channel	Bottom	E 4	22.5	0.00	6.4	276	7.4					
	Mid-depth	E 5	22.5	0.00	6.4	273	7.3	34	1.76	0.223	15	0
	Surface	E 6	22.8	0.24	5.2	280	7.3					
Pennsylvania Side	Bottom	E 7	22.6	0.00	6.4	267	7.3					
	Mid-depth	E 8	22.6	0.00	7.5	281	7.4	34	1.50	0.223	14	7
	Surface	E 9	23.0	0.00	5.2	283	7.3					

* Section E on maps.
** Low tido at 11:25 AM

Table 14

WATER CHARACTERISTICS OF THE DELAWARE RIVER
DELAWARE RIVER BRIDGE SECTION*, HIGH TIDE**
September 15, 1946. Sampling started at 4 30 PM

Station	Sample position	Position designation	Temperature degrees Centigrade	Dissolved oxygen p.p.m.	Oxygen consumed from $KMnO_4$ p.p.m.	Specific conductance mho x 10^{-6} @ 25° C	pH	Total carbonates p.p.m.	Total ammonia p.p.m.	Total phosphates p.p.m.	Total chlorides p.p.m.	Total sulfates p.p.m.
New Jersey Side	Bottom	E 1	23.0	0.00	14.5	279	7.4					
	Mid-depth	E 2	23.0	0.00	11.0	232	7.2	32	2.32	0.214	15	2
	Surface	E 3	23.0	0.00	12.2	273	7.3					
Channel	Bottom	E 4	23.0	0.00	13.3	241	7.2					
	Mid-depth	E 5	23.0	0.00	11.0	286	7.3	33	2.40	0.171	16	2
	Surface	E 6	23.0	0.05	5.8	243	7.3					
Pennsylvania Side	Bottom	E 7	23.0	0.00	8.7	298	7.3					
	Mid-depth	E 8	23.0	0.00	6.4	302	7.3	31	2.34	0.180	16	8
	Surface	E 9	23.0	0.00	7.5	297	7.3					

* Section E on maps.
** High tide at 4:00 PM

Table 15

WATER CHARACTERISTICS OF THE DELAWARE RIVER
RIVERTON, NEW JERSEY SECTION*, HIGH TIDE**
September 17, 1946. Sampling started at 6:30 AM

Station	Sample position	Position designation	Temperature degrees Centigrade	Dissolved oxygen p.p.m.	Oxygen consumed from $KMnO_4$ p.p.m.	Specific conductance mho x 10^{-6} @ 25° C.	pH	Total carbonates p.p.m.	Total ammonia p.p.m.	Total phosphates p.p.m.	Total chlorides p.p.m.	Total sulfates p.p.m.
New Jersey Side	Bottom	F 1	21.5	2.41	5.8	228	7.4					
	Mid-depth	F 2	21.5	1.99	4.6	230	7.5	38	1.10	0.130	11	0
	Surface	F 3	22.0	1.89	4.0	230	7.4					
Channel	Bottom	F 4	21.5	1.13	5.2	243	7.2					
	Mid-depth	F 5	21.5	0.43	5.2	242	7.4	37	1.04	0.150	12	4
	Surface	F 6	22.0	0.85	4.0	251	7.2					
Pennsylvania Side	Bottom	F 7	21.5	0.17	5.2	264	7.3					
	Mid-depth	F 8	21.5	0.00	5.2	262	7.4	36	1.44	0.196	13	4
	Surface	F 9	22.0	0.17	5.2	260	7.4					

* Section F on maps.

** High tide at 6:26 AM

Table 16
WATER CHARACTERISTICS OF THE DELAWARE RIVER
RIVERTON, NEW JERSEY SECTION*, LOW TIDE**
September 17, 1946. Sampling started at 1:30 PM

Station	Sample position	Position designation	Temperature degrees Centigrade	Dissolved oxygen p.p.m.	Oxygen consumed from $KMnO_4$ p.p.m.	Specific conductance mho x 10^{-6} @ 25° C.	pH	Total carbonates p.p.m.	Total ammonia p.p.m.	Total phosphates p.p.m.	Total chlorides p.p.m.	Total-sulfates p.p.m.
New Jersey Side	Bottom	F 1	23.0	6.35	2.3	223	7.7					
	Mid-depth	F 2	23.0	6.13	0.6	222	7.5	32	0.74	0.082	10	13
	Surface	F 3	23.5	6.13	1.7	222	7.7					
Channel	Bottom	F 4	22.5	5.52	1.7	223	7.4					
	Mid-depth	F 5	22.5	5.46	0.0	230	7.5	33	1.20	0.124	9	1
	Surface	F 6	23.0	5.52	0.6	229	7.6					
Pennsylvania Side	Bottom	F 7	22.5	5.46	0.6	234	7.5					
	Mid-depth	F 8	22.5	5.62	0.0	236	7.6	29	0.94	0.133	6	5
	Surface	F 9	23.0	5.46	0.6	237	7.7					

* Section F on maps
** Low tide at 1:34 PM

Table 17.

WATER CHARACTERISTICS OF THE DELAWARE RIVER
CHANNEL SAMPLES BEVERLY, NEW JERSEY TO PORT JERVIS, NEW YORK
September 18-22, 1946

Station	Sample position	Position designation	Temperature degrees Centigrade	Dissolved oxygen p.p.m.	Oxygen consumed from $KMnO_4$ p.p.m.	Specific conductance mho x 10^{-6} @ 25° C.	pH	Total carbonates p.p.m.	Total ammonia p.p.m.	Total phosphates p.p.m.	Total chlorides p.p.m.	Total sulfates p.p.m.
Beverly	Bottom	G 1	22.0	5.34	0.0	222	7.7					
(High Tide)	Mid-depth	G 2	22.0	5.28	0.0	230	7.7	35	0.25	0.121	6	4
	Surface	G 3	22.0	5.60	0.0	226	7.5					
Burlington	Bottom	H 1	22.5	5.34	0.6	228	7.5					
(High Tide)	Mid-depth	H 2	22.5	5.38	0.0	230	7.5	35	0.10	0.138	5	17
	Surface	H 3	22.5	5.38	0.0	234	7.5					
Bordentown	Surface	L 1	22.0	6.33	6.2	228	7.6	33	0.50	0.030	7	0
Lambertville	Mid-depth	M 1	21.6	7.55	8.1	211	7.9	37	0.45	0.006	7	0
Easton	Surface	N 1	21.3	7.08	5.8	251	7.3	35	0.54	0.115	4	10
Port Jervis	Mid-depth	P 1	19.0	7.94	7.2	56	7.9	12	0.60	0.050	1	1

Shown on maps as Sections G, H, L, M, N, P.

Table 18

WATER CHARACTERISTICS OF THE DELAWARE RIVER
DELAWARE CITY, DELAWARE SECTION*, HIGH TIDE**
September 20, 1946. Sampling started at 7:00 AM

Station	Sample position	Position designation	Temperature degrees Centigrade	Dissolved oxygen p.p.m.	Oxygen consumed from $KMnO_4$ p.p.m.	Specific conductance mho x 10^{-6} @ 25° C.	pH	Total carbonates p.p.m.	Total ammonia p.p.m.	Total phosphates p.p.m.	Total chlorides p.p.m.	Total sulfates p.p.m.
Delaware Side	Bottom	I 1	22.0	6.62	32.6	11,570	7.5	33	0.26	0.085	3290	498
	Surface	I 2	21.8	6.98	20.3	11,730	7.4					
Channel	Bottom	I 3	21.6	6.78	35.7	12,280	7.5					
	Mid-depth	I 4	21.8	6.84	33.4	12,230	7.4	38	0.17	0.088	3520	534
	Surface	I 5	22.0	6.78	11.4	11,900	7.6					
New Jersey Side	Bottom	I 6	22.0	6.88	11.0	12,280	7.6					
	Mid-depth	I 7	22.0	7.00	10.2	12,200	7.8	38	0.17	0.088	3560	545
	Surface	I 8	22.0	6.98	9.0	12,000	7.8					

*Section I on maps.

** High tide at 6:35 AM

15898

Table 19

WATER CHARACTERISTICS OF THE DELAWARE RIVER
DELAWARE CITY, DELAWARE SECTION*, LOW TIDE **
September 20, 1946. Sampling started at 1:00 PM

Station	Sample position	Position designation	Temperature degrees Centigrade	Dissolved oxygen p.p.m.	Oxygen consumed from $KMnO_4$ p.p.m.	Specific conductance mho x 10^{-6} @ 25° C.	pH	Total carbonates p.p.m.	Total ammonia p.p.m.	Total phosphates p.p.m.	Total chlorides p.p.m.	Total sulfates p.p.m.
Delaware Side	Bottom	I 1	23.2	7.03	15.0	8,350	8.3	32	0.27	0.082	2350	370
	Surface	I 2	23.1	7.04	13.8	8,450	8.2					
Channel	Bottom	I 3	22.7	6.05	17.3	8,450	8.3					
	Mid-depth	I 4	22.7	6.21	12.0	8,270	8.3	34	0.26	0.098	2280	364
	Surface	I 5	23.0	6.52	12.8	8,200	8.3					
New Jersey Side	Bottom	I 6	22.8	6.32	19.8	9,320	8.2					
	Mid-depth	I 7	23.0	6.40	12.9	8,760	8.3	34	0.28	0.067	2440	386
	Surface	I 8	23.3	6.42	11.2	8,270	8.3					

*Section I on maps

**Low tide at 1:20 PM

Table 3

WATER CHARACTERISTICS OF THE DELAWARE RIVER
PENNSVILLE, NEW JERSEY SECTION*, LOW TIDE*
September 21, 1946. Sampling started at 3:00 AM

Station	Sample position	Position designation	Temperature degrees Centigrade	Dissolved oxygen p.p.m.	Oxygen consumed from $KMnO_4$ p.p.m.	Specific conductance mho x 10^{-6} @ 25° C.	pH	Total carbonates p.p.m.	Total ammonia p.p.m.	Total phosphates p.p.m.	Total chlorides p.p.m.	Total sulfates p.p.m.
New Jersey Side	Bottom	J 1	22.5	4.87	9.1	6490	7.0					
	Mid-depth	J 2	22.5	3.94	6.3	5000	7.0	23	1.00	0.038	1625	239
	Surface	J 3	22.5	3.89	7.2	4740	6.9					
Channel	Bottom	J 4	22.5	2.96	6.7	4850	6.8					
	Mid-depth	J 5	22.5	2.44	6.2	4500	6.8	25	0.68	0.050	1165	220
	Surface	J 6	22.5	2.44	16.6	4290	6.8					
Delaware Side	Bottom	J 7	22.5	1.66	4.7	4070	6.7					
	Mid-depth	J 8	22.5	1.66	3.0	3990	6.9	23	0.81	0.060	1075	212
	Surface	J 9	22.5	1.71	5.6	4010	6.8					

* ~~Section I on maps~~
* Low tide at 2:37 AM

Table 4

WATER CHARACTERISTICS OF THE DELAWARE RIVER
PENNSVILLE, NEW JERSEY SECTION*, HIGH TIDE **
September 21, 1946. Sampling started at 8:30 AM

Station	Sample position	Position designation	Temperature degrees Centigrade	Dissolved oxygen p.p.m.	Oxygen consumed from $KMnO_4$ p.p.m.	Specific conductance mho x 10^{-6} @ 25° C.	pH	Total carbonates p.p.m.	Total ammonia p.p.m.	Total phosphates p.p.m.	Total chlorides p.p.m.	Total sulfates p.p.m.
New Jersey Side	Bottom	J 1	22.3	6.01	26.5	--	6.9					
	Mid-depth	J 2	22.0	5.92	25.3	8440	6.8	18	0.75	0.072	2380	366
	Surface	J 3	22.0	5.70	22.4	--	7.0					
Channel	Bottom	J 4	22.0	6.01	34.6	8900	6.9					
	Mid-depth	J 5	22.0	5.92	24.8	8040	6.9	23	0.40	0.033	2320	369
	Surface	J 6	22.2	5.44	21.1	7050	6.8					
Delaware Side	Bottom	J 7	22.4	5.34	27.8	7050	6.8					
	Mid-depth	J 8	22.0	5.55	22.6	7300	7.0	25	0.60	0.038	2000	326
	Surface	J 9	22.5	5.55	22.5	7000	6.8					

~~* Section I on maps~~
** High tide 8:14 AM

Table 22

Water characteristics of the Delaware River, Bridgeport, New Jersey section*

October 21, 1946. High tide. Sampling started at 10:10 AM**

Station	Sample position	Position designation	Temperature degrees Centigrade	Dissolved oxygen p.p.m.	Specific conductance mho x 10^{-6} at 25° C.	pH
New Jersey side	Bottom	A 1	16.8	0.61	1,600	6.63
	Mid-depth	A 2	16.7	0.80	1,438	6.60
	Surface	A 3	16.7	0.95	1,210	6.58
Mid-channel	Bottom	A 45	16.8	0.21	2,140	7.70
	Mid-depth	A 55	16.7	0.58	1,905	7.68
	Surface	A 65	16.8	0.79	1,850	7.70
Pennsylvania side	Bottom	A 10	16.7	0.11	1,720	6.45
	Mid-depth	A 11	16.9	0.62	1,660	6.50
	Surface	A 12	16.9	0.45	1,715	6.63

* Section A on maps.

** High tide at 10:11 AM

15898.

Table 23

Water characteristics of the Delaware River, Bridgeport, New Jersey section*

Station	Sample position	Position designation	Temperature degrees Centigrade	Dissolved oxygen p.p.m.	Specific conductance mho x 10^{-6} at 25° C	pH
October 21, 1946. Tide half out. Sampling started at 1:15 PM**						
New Jersey side	Bottom	A 1	16.4	0.36	664	6.60
	Mid-depth	A 2	16.7	0.20	632	6.62
	Surface	A 3	16.5	0.46	622	6.66
Mid-channel	Bottom	A 45	17.2	0.12	980	6.60
	Mid-depth	A 55	17.0	0.36	945	6.64
	Surface	A 65	17.0	0.06	874	6.63
Pennsylvania side	Bottom	A 10	17.0	0.17	1,190	6.64
	Mid-depth	A 11	17.0	0.29	1,105	6.67
	Surface	A 12	17.0	0.22	1,117	6.65
October 21, 1946. Tide half in. Sampling started at 6:05 PM***						
Mid-channel	Bottom	A 45	16.7	0.04	432	6.81
	Mid-depth	A 55	16.7	0.29	422	6.85
	Surface	A 65	16.7	0.12	422	6.80

* Section A on maps

** High tide at 10:11 AM

*** Low tide at 4:59 PM

15898

Table 24

Water characteristics of the Delaware River, Bridgeport, New Jersey section*

October 21, 1946. Low tide. Sampling started at 4:05 PM***

Station	Sample position	Position designation	Temperature degrees Centigrade.	Dissolved oxygen p.p.m.	Specific conductance mho x 10^{-6} at 25° C	pH
New Jersey side	Bottom	A 1	16.7	0.32	607	6.73
	Mid-depth	A 2	16.7	0.12	610	6.81
	Surface	A 3	16.7	0.20	605	6.80
Mid-channel	Bottom	A 45	16.7	0.12	441	6.72
	Mid-depth**	A 55	16.7	0.46	439	6.76
	Surface	A 65	16.7	0.19	408	6.73
Pennsylvania side	Bottom	A 10	16.8	0.16	591	6.73
	Mid-depth	A 11	16.7	0.09	564	6.70
	Surface	A 12	16.7	0.37	486	6.75

* Section A on maps.

** This sample carried 3.3 p.p.m. SO_4, 53 p.p.m. Cl, 0.19 p.p.m. PO_4, 7.2 p.p.m. Mg and 20.6 p.p.m. Ca.

*** Low tide at 4:59 PM

15898

Table 25

Water characteristics of the Schuylkill River
Penrose Ferry Bridge, Philadelphia, Pa. section*

Station	Sample position	Position designation	Temperature degrees Centigrade	Dissolved oxygen p.p.m.	Specific conductance mho x 10^{-6} at 25° C	pH
October 24, 1946. Low tide. Sampling started at 8:15 AM						
Mid-channel	Bottom	D 15	18.0	0.00	379	6.80
	Mid-depth	D 25	18.7	0.00	473	6.80
	Surface	D 35	19.0	0.00	493	6.80
October 24, 1946. Tide half in. Sampling started at 10:15 AM						
Mid-channel	Bottom	D 15	18.0	0.00	350	6.78
	Mid-depth	D 25	18.5	0.00	400	6.77
	Surface	D 35	18.8	0.00	420	6.77
October 24, 1946. Tide high. Sampling started at 1:00 PM						
Mid-channel	Bottom	D 15	15.9	0.04	317	6.77
	Mid-depth	D 25	18.1	0.02	348	6.77
	Surface	D 35	17.2	0.06	439	6.77

15899

*Section D on maps.

Table 26

Water characteristics of the Delaware River, Riverton, New Jersey section*

15898

Station	Sample position	Position designation	Temperature degrees Centigrade	Dissolved oxygen p.p.m.	Specific conductance mho x 10^{-6} at 25° C	pH
		October 22, 1946. High tide. Sampling started at 12:30 PM.				
Mid-channel	Bottom	F-4	16.0	5.95	188	6.68
	Mid-depth	F-5	16.2	5.15	191	6.98
	Surface	F-6	16.3	4.96	194	6.97
		October 22, 1946. Tide half out. Sampling started at 3:30 PM				
Mid-channel	Bottom	F-4	15.7	7.41	174	7.05
	Mid-depth	F-5	15.5	8.01	175	7.11
	Surface	F-6	15.4	8.07	177	7.14
		October 22, 1946. Tide low. Sampling started at 7:00 PM				
Mid-channel	Bottom	F-4	15.3	8.86	173	7.20
	Mid-depth**	F-5	15.2	8.86	171	7.28
	Surface	F-6	15.0	8.91	174	7.30

* Section F on maps.
** This sample carried 14.3 p.p.m. SO_4, 8.5 p.p.m. Cl, 0.11 p.p.m. PO_4, 3.4 p.p.m. Mg and 16.5 p.p.m. Ca.

Table 27

Water characteristics of the Delaware River, Pennsyille, New Jersey section*

15890

Station	Sample position	Position designation	Temperature degrees Centigrade	Dissolved oxygen p.p.m.	Specific conductance mho x 10^{-6} at 25° C.	pH
October 19, 1946. Low tide sampling started at 2:35 P.M.**						
Mid-channel	Bottom	J-4	17.4	2.54	191	6.83
	Mid-depth	J-5	17.6	1.57	237	6.88
	Surface	J-6	17.7	1.71	254	6.86
October 19, 1946. High tide sampling started at 7:45 P.M.						
Mid-channel	Bottom	J-4	16.8	6.45	8,720	7.35
	Mid-depth	J-5	17.1	6.52	8,720	7.28
	Surface	J-6	17.0	6.26	8,450	7.34

*Section J on maps
**Low tide at 1:33 PM: high tide at 7:23 PM

Table 28.

Water characteristics of the Delaware River, Bordentown, New Jersey section*

October 20, 1946. Low tide sampling started at 5:25 P.M.**

15899

Station	Sample position	Position designation	Temperature Centigrade degrees	Dissolved oxygen p.p.m.	Specific conductance mho x 10^{-6} at 25° C.	pH
Mid-channel	Bottom	L 3	13.6	8.73	223	7.53
	Mid-depth	L 2	13.5	8.82	159	7.53
	Surface	L 1	13.5	9.10	157	7.50

* Section L on maps
** Low tide at 6:41 PM