Chemical Quality of Water Brookhaven National Laboratory and Vicinity, Suffolk County New York

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GEOLOGICAL SURVEY BULLETIN 1156-D

This report concerns work done on behalf of the U.S. Atomic Energy Commission

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

De Laguna—WATER, BROOKHAVEN NATIONAL LABORATORY AND VICINITY, SUFFOLK COUNTY, N.Y.—Geological Survey Bulletin 1156-D

Chemical Quality of Water Brookhaven National Laboratory and Vicinity, Suffolk County New York

By WALLACE DE LAGUNA

STUDIES OF SITES FOR NUCLEAR ENERGY FACILITIES—
BROOKHAVEN NATIONAL LABORATORY

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By Wallace de Laguna

ABSTRACT

This report tabulates and interprets the results of chemical analyses (including radioactivity) of about 300 water samples collected from wells, lakes, and rivers in the vicinity of Brookhaven National Laboratory during the period 1948–53. The data presented are intended to be used as norms for problems of water contamination that may arise in the future.

Fourteen samples of ground water contained a very low level of radioactivity, the maximum being 5×10^{-14} curies per milliliter, which probably represents natural activity in the water. Beta activity was found in 55 surface-water samples (maximum, 3.7×10^{-13} curies per milliliter). This relatively large number of radioactive samples is partly due to the fact that samples were collected in October 1951 when fallout from atom bomb tests in Nevada first made its appearance in the area.

One significant result of the study was the identification of widespread ground-water contamination, marked by high nitrate content, from the leaching of fertilizer in the intensively farmed areas, and a similar local contamination of ground water by cesspools.

INTRODUCTION

Recognition of any unusual changes in quality of ground water and surface water and of the causes of the changes is necessary in the safeguarding of public water supplies. The purpose of this study was to determine the range in values of chemical constituents, radioactivity, and physical characteristics of the natural water supplies in central Suffolk County, N.Y., for the period of sampling, 1948–53. The data are intended for use as norms for problems of water contamination that may arise in the future.

SAMPLING AND ANALYTICAL PROCEDURES

From 1948 through 1950 about 100 ground-water and surface-water samples were collected from 29 wells and 19 lakes and rivers for chemical analysis by the U.S. Geological Survey and for radiochemical analysis by the National Bureau of Standards. For a second program, which ran from November 1950 through March 1953, about 200 samples were collected in rotation from 15 wells and 10 surface-water sampling locations. Specific conductance, pH, chloride, and nitrate concentrations of these samples were determined by the U.S. Geological Survey, and radioactivity determinations were made by the Health Physics group at Brookhaven National Laboratory. The purpose of this second program was to gain a better insight into the problems that would be encountered by a continuing program intended to monitor the water resources of the area for radioactive contamination. Determination of the stable constitutents presented no problems, although, except for the pH determinations, the accuracy of the analysis was less than that of the determinations made by the Geological Survey in Washington. As anticipated, however, the determinations of radioactivity were complicated by occasional apparent high counts, many of which, when investigated further, seemed to be due to instrumental error, variations in background, or some similar spurious source. Such difficulties are to be expected in very low-level counting. A second and at the time quite unexpected complication arose from the contamination of surface-water samples by the "fallout" from atom-bomb tests in Nevada during the period of the second program. This is described in more detail under "Organization and presentation of data."

The infrequent reports of apparent radioactive contamination in surface-water samples were not an important drawback to the attempt to monitor the water resources of the area, because the results of the analyses were available within a few days and any suspect reports could be checked immediately. Reliability of the ground-water samples for indicating whether the water resources were being contaminated was doubted from the start of the program, however. The reasons for this skepticism depend on the probable pattern of movement of contamination reaching the ground water or the streams. The routine collection and analysis of water samples were finally discontinued in March of 1953, therefore, because the monitoring program seemed to be basically unsound.

Results of the chemical analyses made at Brookhaven National Laboratory for each sampling point are given immediately after the data obtained from the analyses made in Washington (table 6). The chemical data obtained at Brookhaven were not used in preparing the graphs that show the distribution of concentrations of chloride or nitrate, the values of specific conductance, or the values of pH, because the Washington data are considered to be more accurate.

ORGANIZATION AND PRESENTATION OF DATA

The most significant result of the study of the chemical quality of water in central Suffolk County was the identification of widespread ground-water contamination from the long-continued leaching of fertilizer in the intensively farmed areas and from the somewhat similar local contamination of the ground water by cesspools. Both types of contamination are marked by an increase in nitrate, but the amounts of many of the other ions in solution were changed also. In order not to confuse these contaminated samples with what we may call the "normal" ground water, the samples are divided into a "high-nitrate" group and a "normal" group, with the dividing line set at 10 ppm (parts per million) nitrate. In borderline cases the amount of dissolved solids was also considered, for most of the samples that seemed to be contaminated on a consideration of the concentrations of all of the ions present had more than 60 ppm of dissolved solids. Probably some of the samples whose nitrate content ranged from 4 to 10 ppm and whose dissolved-solids content ranged from 50 to 60 ppm are very slightly contaminated, but their classification is speculative. The high-nitrate samples were further subdivided into water contaminated by fertilizers and water contaminated by cesspools. These subgroups will be described more fully below.

The surface-water samples are divided into two groups—those from rivers, which includes ponded sections of streams as well as rapidly flowing water, and those from lakes, in which the water is stagnant because it has no surface outlet. Only four such lakes were sampled: Lake Ronkonkoma, Artist Lake, Long Pond (Lake Panamoke), and Deep Pond (Lake Wauwepex). All these lakes are in kettle-hole depressions. River samples that were collected downstream from one or another of the duck farms are in general identified in the figures that show the distribution of the various materials dissolved in the water. The ducks are an important factor in the contamination of the rivers.

The more detailed treatment within each of these groups has been directed primarily at defining the range and distribution of the individual components and properties. To a large extent, each of the components represented a special problem, and interrelations between components were the exception. An insufficient number of samples and too many variables made a statistical analysis impossible, although some graphs and plottings of a statistical nature have been used. Some statistical analyses seem to be more definitive than they actually are. Until more is known about the factors governing the concentrations of the individual ions in the water, it is very difficult to identify typical or representative samples. A more thorough sampling would be required for a reliable statistical analysis.

Even with the available data, some of the ions, for example, bicarbonate, have a statistically normal distribution, whereas others, for example, calcium, have a skewed distribution. Also, the data suggest that some wells produce water that is consistently high or low in certain ions; for example, a few wells were consistently high in calcium, others consistently low in bicarbonate. None of the wells appeared to be producing water consistently high in silica, iron, or radium.

The concentrations of many of the constituents that were determined are so low that a precise determination of the amount present is not possible, even by an experienced analyst. Representative samples are difficult to collect, for contamination from a variety of causes is all too easy. The data given are the best that could be obtained by careful handling at all stages, but it is still far from perfect.

REPRESENTATIVE ANALYSES OF THE FOUR CLASSES OF WATER

Before undertaking a detailed discussion of the individual constituents, it appears advisable to give the reader a generalized summary of the composition of the four classes of water in the Brookhaven National Laboratory area (table 1). The values shown are what might be expected in a typical sample; they do not show the range of normal variation.

TABLE 1.—*Representative compositions of the four classes of water*

[Except for specific conductance, given in micromhos, and pH, the data are in parts per million]

	Ground water		Rivers	Lakes
	Normal	High-nitrate		
Silica	8	8	8	1
Iron	.2	.4	.2	.1
Calcium	2	25	5	2.5
Magnesium	1.5	6	2	1
Sodium	4	16	4.5	3.5
Potassium	.6	3	.7	.6
Bicarbonate	9	9	10	5
Sulfate	8	80	8	8
Chloride	5	20	6	5.5
Nitrate	.5	40	1.5	.2
Dissolved solids	36	200	42	26
Specific conductance (in micromhos)	50	350	60	50
pH	6.0	6.5	6.8	6.3

DESCRIPTION OF INDIVIDUAL CONSTITUENTS AND PROPERTIES

SILICA

The silica content of most of the ground-water samples was about evenly distributed in the range from 6 to 10 ppm, although a few sam-

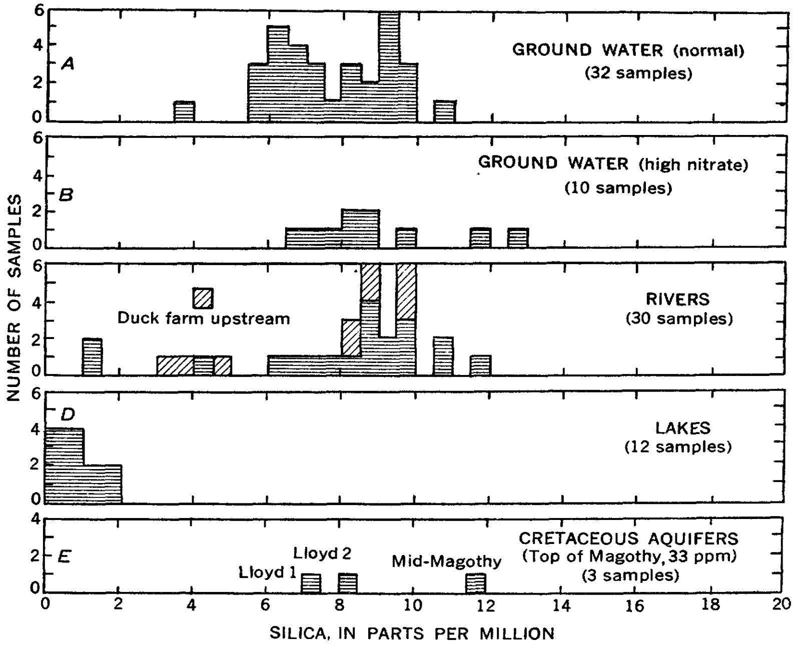

FIGURE 1.—Silica Distribution, parts per million.

ples had as little as 4 ppm or as much as 11 ppm (fig. 1). These are low concentrations for ground water, although not remarkably so; the general range the country over for silica in ground water is 1 to 30 ppm. The silica is probably taken into solution during the chemical decomposition of such silicate minerals as the feldspars and the amphiboles, which are present in large quantities in the glacial sands. The silica in the ground water is probably in colloidal rather than ionic solution. Quartz, which is pure crystalline silica, is virtually insoluble in the ground water of this area. Inspection of the chemical data suggests that none of the wells yields water that is consistently high or low in silica content. Apparently silica content is directly related to neither the concentration of any other constituent present, nor, within the limits of variation in this area, the pH of the water. As the normal range of 6 to 10 ppm in concentration does not even involve a relative range of two to one, silica is one of the more constant constituents of the normal ground water. Silica content, in most of these samples, ranged from 20 to 33 percent by weight of the dissolved solids, although in some of the samples that have a high dissolved-solids content, for example, those from well S3405, it comprised only about 10 percent of the dissolved solids.

Silica content of the rivers ranged from 1.1 to 12 ppm, a much wider range than that observed in the ground water. Silica in most of the samples, however, ranged from 6 to 10 ppm, the same as for ground water. This range is in general what one would expect, as the river water is largely effluent ground water and the composition of the two classes should be very similar. Thus, the few river samples low in silica require an explanation. These low concentrations, ranging from 1.1 to 4.1 ppm, were mostly obtained from various sampling points on the Peconic River during the months of March and April. During this period the Peconic, unlike the other streams that were sampled, gets an appreciable part of its water from direct surface runoff and from swamps and ponds that are at high stage. Possibly this surface runoff had not been in contact with the soil long enough to pick up its usual content of silica, although it had in general the usual quantities of most of the other materials.

The silica content of the river samples, taken from points downstream from duck farms, was the same as that from the unpolluted stream. The presence of the ducks does not appear to affect the silica content.

The silica content of the lakes ranged from 0.2 to 1.7 ppm, which is only 5 to 10 percent of the silica content of the rivers or ground water. The lakes, it is true, receive some direct surface runoff that is low in silica. They also get more water in the form of rain (45 in.) than they lose by evaporation (30 in.), so that there is a small net outflow from the lakes to the ground water. There is some mixing of the lake water and ground water, however, due to both the rise and fall of the water table and to the natural movement of the ground water, which would tend to bring it in on one side of the lake and out on the other. This flow-through is probably least in Artist Lake, which is on the water-table divide in an area where the water-table gradient is particularly low. Thus, the generally low silica content of the lakes may be due in part to a relatively large proportion of surface and rain water that has had a minimum of opportunity to pick up silica, but there is another mechanism that may well be more important. The lakes contain diatoms (Biol. Survey of New York, 1938)—microscopic one-celled plants that build shells of silica—which they extract from the lake water and so lower its silica content. The streams also contain diatoms, although their effect on the silica content of rapidly running water is believed by the author to be negligible. Possibly the diatoms were in some part responsible for the low silica content of 1.5 ppm found in the water flowing out of the ponded reach of the Carmans River at Route 27. This sample was collected on February 13, 1950, but even at this time of year diatoms will be growing actively if the water is not covered by ice.

IRON

Iron content of the normal ground water ranged from 0.01 to 7.5 ppm, by far the widest percentage variation of any constituent in this class of water (fig. 2). Because of this wide range it is not possible to illustrate easily the distribution of the results of the analyses in a histogram; therefore the data have been recalculated to show the cumulated percentage of the samples in each of the four classes having less than the indicated iron content. The resulting curves show that for the normal ground water, about 20 percent of the samples had between 0.01 and 0.1 ppm iron, 60 percent had between 0.1 and 0.5 ppm, and the remaining 20 percent had more than 0.5 ppm iron. The samples appear to fall into three groups—low, medium, and high iron contents. The middle group is the largest, although it has the smallest range in concentration.

Inspection of the chemical analyses in table 6 shows that the variation in iron content of successive samples from the same well is as great as for samples from different wells. For example, the 4 samples from well S2485 had 0.01, 0.02, 0.33, and 1.6 ppm iron, and the 3 samples from well S2476 had 0.04, 0.23, and 1.8 ppm. Apparently none of the wells or areas at the Brookhaven National Laboratory consistently yield water of low, medium, or high iron content.

There are several possible explanations for the apparent erratic variations in iron concentration. Iron, unlike any of the other ions present in appreciable amounts, can exist in two different forms, the ferrous and the ferric. Of these, the ferrous is much more soluble, so that when ground water containing ferrous iron is exposed to the air, or to some other oxidizing agent, iron in excess of about 1 ppm will be precipitated out; the concentratoin, therefore, may be reduced well below this value.

This variation in solubility of the iron in the ground water greatly complicates the problem of getting representative samples to the laboratory. Probably no determination made in water analyses involves more uncertainty than that of iron. One of these uncertainties concerns the classification and reporting of iron hydroxide in the sample but not in solution at the time of analysis. In ground-water samples the Geological Survey customarily assumes that any such iron in suspension was in solution at the time the sample was collected, and that it has subsequently been precipitated out. It is therefore redissolved and included in the amount of iron reported as in the sample. In surface-water samples, however, any iron in suspension is filtered out and is not included as a constituent of the sample. If colloidal iron or fine iron oxide is picked up by the ground water from the aquifer adjacent to the well, from incrustations on the

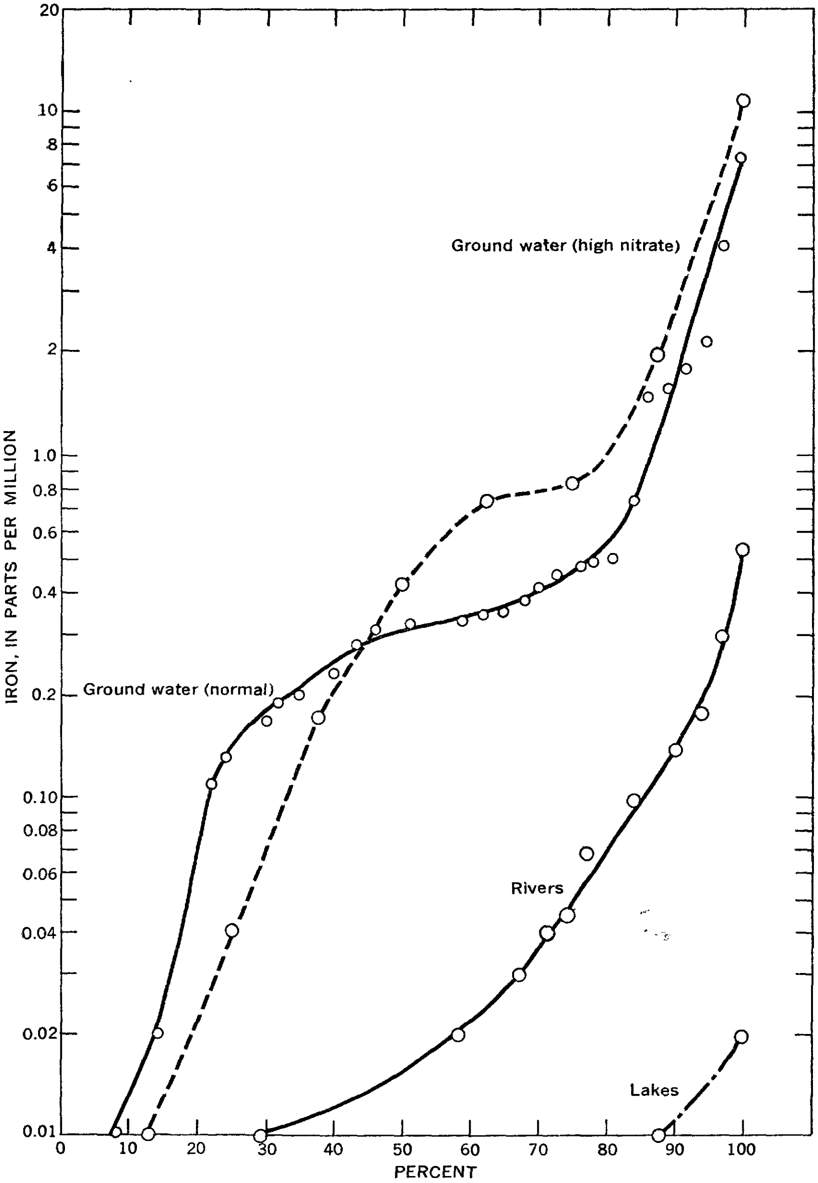

FIGURE 2.—Percent of samples having less than indicated amount of iron.

well screen, or from the well itself, such iron may be reported as though it were a true constituent of the sample and so give an exaggerated impression of the amount of iron present in the ground water.

There are wide variations in the natural concentration of iron in the ground water, for the sand grains in the aquifer are locally coated or even cemented by deposits of iron oxide, showing that although iron is dissolved by the ground water in some places, it is precipitated in others. Study of these irregular natural variations is complicated by variations in reported iron content arising artificially from the sampling and analysis. The same puzzling differences in iron content have been reported from other similar aquifers in other areas and are in no way unusual.

The iron content of the rivers is less than that of the ground water and covers a much narrower range, 0.01 to 0.53 ppm. More than half the samples had 0.02 ppm or less iron, and only two samples had 0.2 ppm or more. Ferrous iron exposed to the air in a moving stream has little opportunity to remain unoxidized, so that the iron content of the river water is undoubtedly less than that of the ground water. The difference in analytical procedure is important also, as may be the fact that the surface-water samples are taken directly from the stream rather than from a well containing cast iron or steel pipe.

The river samples collected at points downstream from duck farms had no more nor less iron than the other river samples.

The iron content of the lakes was even less than that of the rivers. Of the 12 samples analyzed, 11 had 0.01 ppm iron, and one had 0.02 ppm. Because the sampling and analytical procedures are the same for the lakes as for the rivers, the differences must be genuine, and it may be assumed that the opportunity for more complete oxidation and precipitation of the iron in the lake samples is largely responsible. Possibly the water in the lakes had less opportunity to pick up iron than the river water or ground water, but the iron is probably taken into solution as readily as the calcium and magnesium, which in the lake waters are not less concentrated. The lakes, therefore, are probably low in iron because the water in them is unable to hold iron in solution, not because it had little opportunity to pick up the iron.

CALCIUM AND MAGNESIUM

Calcium and magnesium are the only two cations whose concentrations in the natural ground water seem to be interrelated. Both are constituents of a number of silicate minerals, such as the amphiboles and the pyroxenes, which are present in large quantities in the glacial outwash. The weathering of these minerals is the most probable source of the calcium and magnesium in the ground water, as there is little, if any, limestone or dolomite in the glacial deposits.

The histogram (fig. 3) showing the quantities of calcium in the samples of normal ground water indicates an uneven distribution of concentrations in the samples and suggests the possibility of a complex origin for this element. Of the 33 samples of normal ground water analyzed for calcium, 24 had between 1 and 2.8 ppm, 9 had 4.1

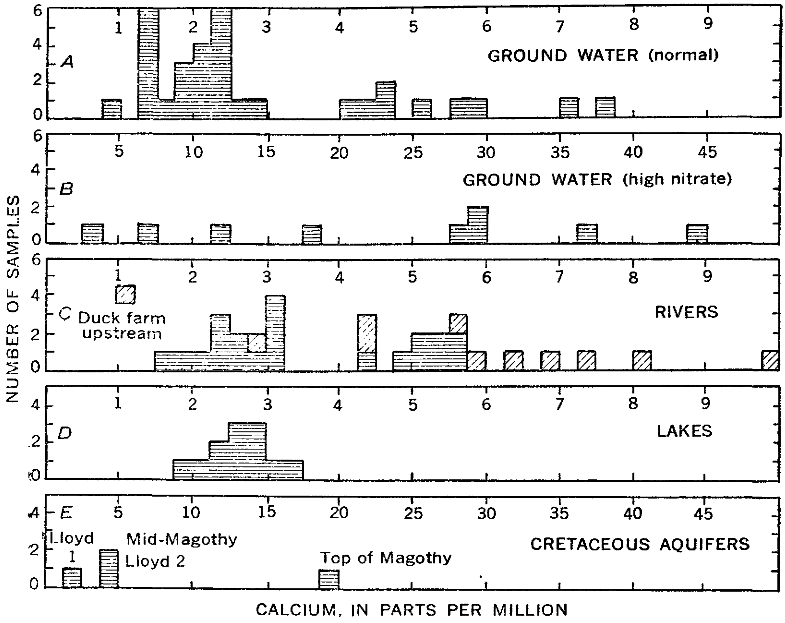

FIGURE 3.—Calcium distribution, parts per million.

to 7.6 ppm. These data suggest that the normal range of calcium is from about 1 to 3 ppm and that additional calcium from some separate or special source has found its way into the samples having 4 ppm or more. This possibility seems even more likely because all 9 of the "high calcium" samples came from just 6 wells: S6425, S2476, S6471, S3405, on the Brookhaven National Laboratory grounds; well S5362 just to the north; and well S9143 a mile or two to the southeast of the Laboratory. Only 1 sample of water from any of these 6 wells had less than 4 ppm calcium, and no samples from any other well believed by the author to yield normal ground water had as much as 3 ppm of calcium.

Thirty-three samples of normal ground water were analyzed for their magnesium content, and the amounts determined ranged from 0.6 to 3.6 ppm (fig. 4). The magnesium showed a distribution into two classes similar to that of the calcium, although the distinction is less clear cut. Twenty-nine samples had 2.0 ppm or less; 4 samples had 2.3 ppm or more. The 4 samples containing 2.3 ppm or more of magnesium came from wells that had yielded calcium-rich water. The magnesium content of all the samples from the calcium-rich wells averaged 2.1 ppm; whereas the average magnesium content of the low-calcium wells, that is, those wells that yielded water containing consistently less than 3 ppm calcium, was only 1.3 ppm. The largest amount of magnesium found in any of the samples from the low-calcium wells was 2.0 ppm.

Nothing about the location of the six high-calcium wells would explain the difference between the character of the water that they produce and that of the other wells. There is no assurance that anything is unusual about them, as the number of samples on which this study is based is not large enough to define clearly minor differences; but the distinction does seem valid. The water from these six wells is also slightly higher in nitrate and in total dissolved solids than the apparent normal ground water, which suggests that these wells may be very slightly contaminated with domestic sewage or with fertilizer, as are the high-nitrate group of wells; but there is nothing in the field evidence to substantiate this possibility. A more extensive sampling program would be required to define the nature and origin of the slight excess of calcium and magnesium.

It is not necessary that both calcium and magnesium be added from some separate source to the water that supplies these wells, for if either one is added, ion exchange will increase the amount of the other. In the samples from these wells calcium and magnesium are the only pair of cations whose exchange involves little or no hysteresis; that is, they are the only pair whose concentration would come to the same equilib-

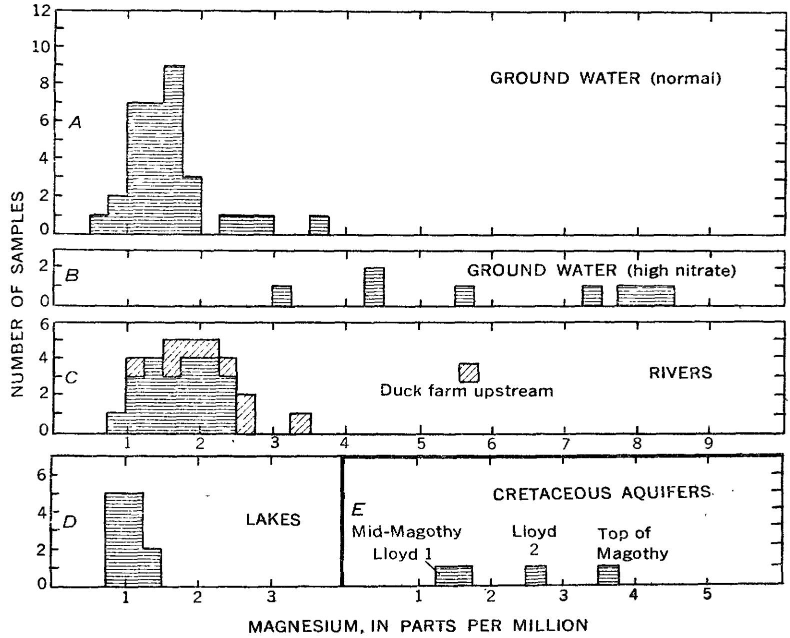

FIGURE 4.—Magnesium distribution, parts per million.

rium ratio as the result of ion exchange no matter which one was initially the more abundant (Kelley, 1948, p. 58).

The calcium content of the river water appeared to be similar to that of the normal ground water and ranged from 1.6 to 10 ppm. All the samples containing more than 5.6 ppm calcium, however, had been collected at points downstream from one of the duck farms, so that the natural maximum range of the river water is about from 1.5 to 6.0 ppm. The magnesium content of the samples from duck-free rivers ranged from 1.0 to 2.3 ppm; the samples from rivers with duck farms had as much as 3.4 ppm magnesium. A general comparison of the samples suggests that the ducks contribute about 2 ppm calcium to the rivers, but hardly more than 0.5 ppm magnesium, although the data are not sufficient for reliable generalization.

The calcium content of the lake samples ranged from 1.9 to 3.3 ppm and the magnesium content, from 0.8 to 1.4 ppm. Thus, the calcium and magnesium contents of the lakes corresponded roughly with the calcium and magnesium content of the low-calcium group of normal ground-water samples.

The surface-water samples showed about the same apparent statistical relation between calcium content and magnesium content that was noted in the normal ground water. In a general way the samples richer in calcium were also richer in magnesium, which may be due to the influence of ion exchange in the ground before the water emerges to join the streams; more likely, it represents the simultaneous addition of both calcium and magnesium at the same time, as by the ducks.

SODIUM

The sodium content of the normal ground water ranged from 3.2 to 6.3 ppm, except for one sample which was reported to have only 2.6 ppm (fig. 5). This two-to-one ratio in range of sodium content is small as compared to that of most of the ions. The sodium reaches the ground water from two sources—the sea and the minerals in the aquifer. Particularly during storms, salt spray is carried aloft from ocean waves by the wind, and when the spray droplets evaporate, tiny salt particles are left as dust in the atmosphere. This dust is brought down by the rain, much of it near the coast, but some of it travels hundreds of miles into the interior (Jackson, 1905). The rain contains, therefore, some of all the ions present in sea water, although only sodium and chloride are present in amounts sufficient to affect noticeably the chemical content of the ground water. The sodium content of the rain averages about 1 ppm (see "Chloride," p. D20), and this is concentrated by evapotranspiration to about 2 ppm in the ground water. Sodium ions of rain plus additional sodium ions from other

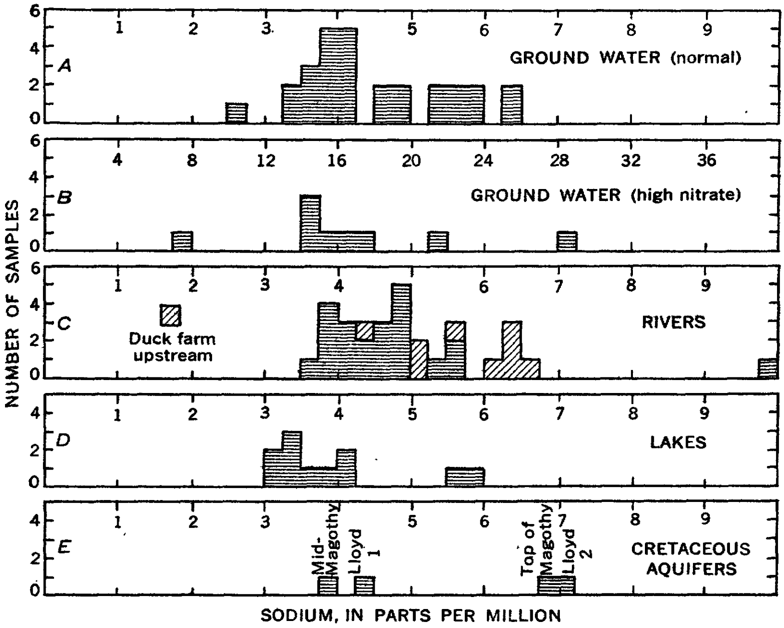

FIGURE 5.—Sodium distribution, parts per million.

sources give the normal ground water an average sodium content of about 4.5 ppm.

The additional sodium is derived from the decomposition of such minerals as the potassic feldspars in the soil zone and in the aquifer. The quantity of sodium so derived may be estimated independently, because this sodium, unlike that which comes from the sea, is not necessarily accompanied by chloride. None of the minerals in the Long Island aquifers contain quantitatively important amounts of chloride. The average sodium content of the normal ground water was 4.5 ppm; the average chloride content, 5.5 ppm. The proportions of sodium to chloride in sea water are such that 5.5 ppm of chloride would be accompanied by 3 ppm of sodium, leaving 1.5 ppm to be derived from the minerals in the soil and the aquifer. This is a somewhat smaller figure than the 2.5 ppm estimated—for this same contribution of sodium by these minerals—from a consideration of the sodium content of the rain. There are several explanations for this discrepancy, and all may contribute towards it. The weakest point is the value for the sodium content of the rain, which was derived from a chloride determination of rainfall described on page D20. This value may be too low, for the rainfall samples were difficult to collect during high winds, when the chloride content of the rain would be at a maximum. In addition, the determination of sodium in water samples in amounts as small as 4 or 5 ppm is difficult for the analyst, and even when skillfully done, is subject to error. Also, if some of the samples are indeed slightly contaminated this, too, could affect the results. Despite these objections, however, the sodium found in the normal ground water on Long Island is probably derived in approximately equal amounts from sea salt in the rain and from the decomposition of minerals.

Examination of the individual analyses suggests that some of the wells, like S6407 and S2485, may have a consistently high sodium content (5 samples average 6.0 ppm), whereas others, like S3405, appear to be low in sodium (3 samples average 3.3 ppm). Well S3405 was one of the six wells yielding water high in calcium and magnesium. Apparently in normal ground water there is no correlation, by either wells or individual samples, of sodium content to the content of any other ion. The samples that are either rich in sodium or poor in sodium are neither rich nor poor in any other constituent.

The sodium content of the river samples closely resembled that of the normal ground water, the amounts found ranging from 3.6 to 6.7 ppm, except for one sample that had 10 ppm. The bicarbonate content of this one sample was also very high, 24 ppm. A large laundry is on the small stream above the sampling point and possibly contributed to the abnormal composition of this sample.

The samples taken downstream from duck farms were in general a little higher in sodium than the other samples. The ducks apparently contributed about 1 ppm of sodium to the streams on which they live.

The sodium content of 3 of the lakes ranged from 3.2 to 4.2 ppm. The 2 samples from the fourth lake, Deep Pond, however, had 5.7 and 5.8 ppm sodium. A Boy Scout summer camp is on this lake, and possibly the sewage from the camp may have slightly increased the sodium content of Deep Pond; but the water in the lake is, in other respects, like that of the other lakes. Its high apparent sodium content may be due to the small number of samples analyzed; if more data were available, the apparent difference might vanish.

POTASSIUM

The potassium content of the samples of natural ground water ranged from 0.4 to 2.0 ppm, except for 1 sample which was reported as having 5.8 ppm (fig. 6). This value is so unusually large that it is suspected of being in error. The analyses for potassium were made before the use of the flame photometer had become routine, so that these data are perhaps the least accurate values in the table. For this reason only the most general conclusions will be made.

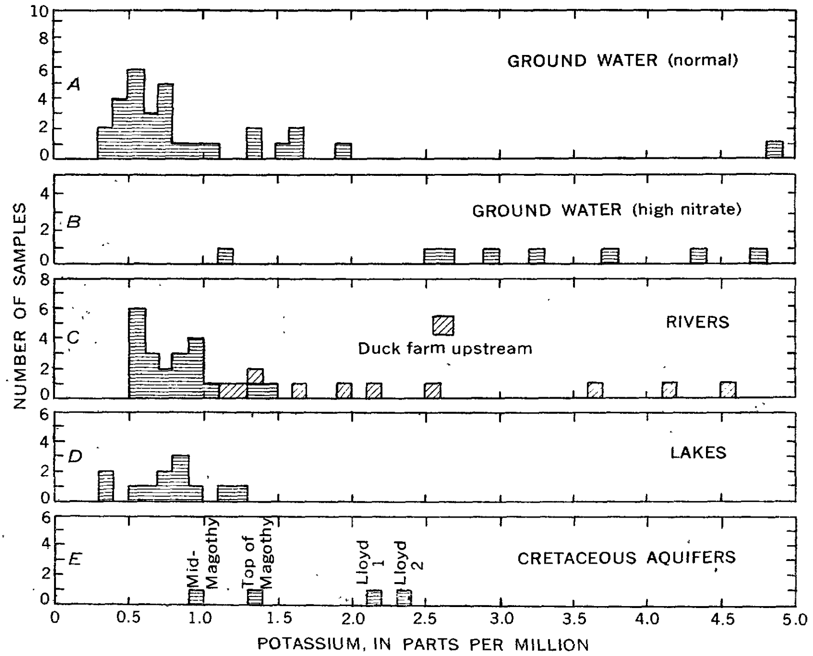

FIGURE 6.—Potassium distribution, parts per million.

If the glacial outwash is assumed to have a bulk mineral composition roughly equivalent to a mixture of quartz sand and ground up quartz diorite or granodiorite, then it should contain roughly equal amounts of potassium, sodium, and magnesium, and about twice this amount of calcium. The average amounts of calcium, magnesium, and of mineral-derived sodium found in the normal ground water are, respectively, about 2.5, 1.5, and 2.0 ppm. The average potassium content of these same samples was about 0.7 ppm; even with the imperfect and incomplete data available, it is clear that potassium is present in the normal ground water in a smaller proportion than it is in the soil or the minerals of the upper Pleistocene aquifer. Clays, in general, are somewhat richer in potassium than are the igneous rocks from which they were derived, the potassium either being bound up in the residuals of the least weathered minerals, or picked up by adsorption or ion exchange by the new clay minerals formed by the weathering (Kelley, 1948, p. 106, ff.; Foster, 1949, p. 647). The clay minerals most effective in the exchange relations between calcium and magnesium are probably not the most effective in the adsorption of potassium (Kelley, 1948, p. 61). We may assume, then, that enough potassium to supply the ground water with about 1.5 to 2.0 ppm was probably set free by mineral weathering, but that roughly half of this was held back in some way and prevented from going into solution.

The six wells (see "Calcium and Magnesium," p. D10) that yielded water rich in calcium and magnesium, appear also to have furnished samples somewhat richer than average in potassium. The difference is not clear cut, however, and examination of the individual samples shows little correlation between the amount of potassium present and the concentration of any other ion. This is not surprising if the factors governing the occurrence of potassium in the ground water are largely controlled by the clay minerals and are peculiar to that ion.

The potassium content of the rivers ranged from 0.6 to 4.6 ppm, although all the samples with more than 1.5 ppm were taken from points downstream from one or another of the duck farms. It is apparent that the ducks contribute 2 to 4 ppm of potassium to the streams on which they are raised. In streams, unlike ground water which is contaminated by sewage or fertilizer, adsorption in the soil has little or no opportunity to remove potassium.

The potassium content of the lake-water samples ranged from 0.4 to 1.3 ppm. This range agreed fairly closely with the range of concentrations found in the normal ground water and the duck-free rivers, although the average potassium content of the lakes is perhaps a little lower.

BICARBONATE

The bicarbonate in the samples of normal ground water ranged from 1 to 20 ppm (fig. 7). The great majority of the samples, however, had between 4 and 12 ppm, and the extremes of both high and low concentration were from only a few samples. Where more than one sample had been taken from the same well. the bicarbonate content generally showed wide variations, although both of the samples from well S5362 (table 6) were very high (18 and 20 ppm), and all four from well S6405 (table 6) were very low (1, 2, 3, and 4 ppm). There was no apparent correlation between the amount of bicarbonate in any sample and the amount present of any other ion, but there did appear to be a relation between bicarbonate and pH. In a general way, the samples with a low pH had less bicarbonate, and high values of each also went together. The same relation was also observed in the river-water samples, where it was perhaps even more clearly marked.

As there is little, if any, limestone or other carbonate rock in the area, the bicarbonate probably comes indirectly from the carbon dioxide in the air, a gas largely picked up by the water in the soil zone (Foster, 1949, p. 649). This dissolved carbon dioxide makes the ground water slightly acid, which helps it to decompose the silicate minerals in the soil. This sets free such cations as calcium, sodium, and potassium, which then go into solution in the ground water. Pure water attacks silicate minerals very slowly.

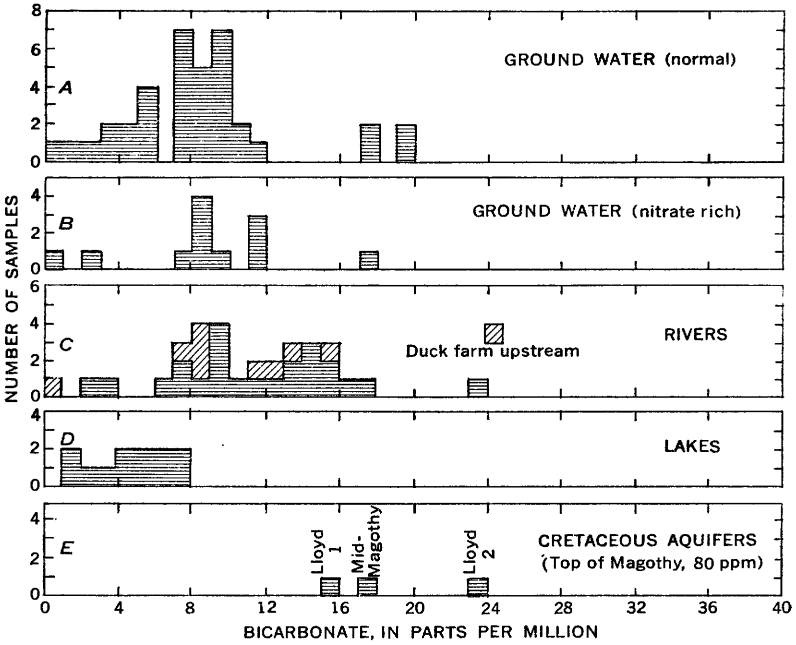

FIGURE 7.—Bicarbonate distribution, parts per million.

The bicarbonate content of the river-water samples was much the same as that in the ground water, and ranged from 0 to 24 ppm. In the river water, however, the average bicarbonate content was about 10 ppm, as compared to an average of about 8 ppm for the ground-water samples. The number of samples may not be large enough to be conclusive, but they are sufficient to suggest that the difference is probably genuine. The samples of river water taken downstream from duck farms contain the same amount of bicarbonate as those from the other streams.

The bicarbonate content of the lake-water samples ranged from 2 to 8 ppm, and averaged about 5 ppm. This is definitely less bicarbonate than is in the ground water or in the rivers.

Bicarbonate is one of the most variable constituents in the uncontaminated surface and ground water. Concentration of bicarbonate in such water ranges from 0 to 40 percent of the dissolved-solids content. There is no clear explanation for such wide variations in concentration in otherwise similar samples from apparently similar wells and streams. Perhaps the fact that the bicarbonate is originally derived from a gas in the soil zone and results from a variety of chemical reactions in the ground may be responsible, for this would probably introduce a wide variety of factors.

SULFATE

The sulfate content of the samples of normal ground water ranged from 2.6 to 19 ppm (fig. 8). The distribution of concentrations over this range was fairly uniform, although there were only 2 samples with more than 14 ppm of sulfate. Successive samples from the same well were, in general, similar to one another in sulfate content, but there were marked differences between samples from nearby wells. For example, all 5 samples from well S3197, one of the Laboratory's own supply wells, had between 4 and 5 ppm sulfate, whereas all 4 samples from well S2485, also on Laboratory property a little more than a mile away, had 10 or 11 ppm sulfate. There is no apparent correlation, sample by sample, between sulfate content and the content of any other ion, nor are the wells that apparently yield consistently sulfate-rich or sulfate-poor water notable in any other respect.

No primary sulfur-bearing minerals have been found on Long Island, although some of the Cretaceous deposits contain small amounts of secondary iron sulfide. The sulfate is probably derived from impurities in the air, such as sulfur dioxide and hydrogen sulfide, and some of the sulfate is brought down with the rain. Much sulfate also is extracted from the air by plants and by bacteria growing in the soil and is picked up by the water in the soil zone. (Alway and others, 1937, p. 229–238; Wilson, 1921, p. 226–229).

The sulfate content of the river samples ranged from 4 to 12 ppm, a little less variation than that shown by the ground-water samples; however, the difference is probably not significant. The river samples collected downstream from duck farms were all in the top half of the group in terms of sulfate content; apparently the ducks contribute 1 or 2 ppm sulfate to the streams on which they live.

The sulfate content of the lake samples ranged from 5.5 to 9.1 ppm, about the same as that for the rivers. Successive samples from the same lake were remarkably constant; Lake Panomoka and Artist Lake were comparatively low (5.0 to 5.9 ppm) whereas Deep Pond and Lake Ronkonkoma were higher (8.1 to 8.2 ppm).

CHLORIDE

The chloride content of the normal ground-water samples ranged from 3.8 to 8.9 ppm, except for 1 sample which was reported as having 12 ppm (fig. 9). This sample came from one of the Brookhaven National Laboratory's supply wells where the water is chlorinated. Although precautions were taken against contamination, both the validity of the sample and the accuracy of the analysis are questionable.

The chloride in the normal ground water must come almost entirely in the form of windborne spray or dust from the ocean, as mentioned

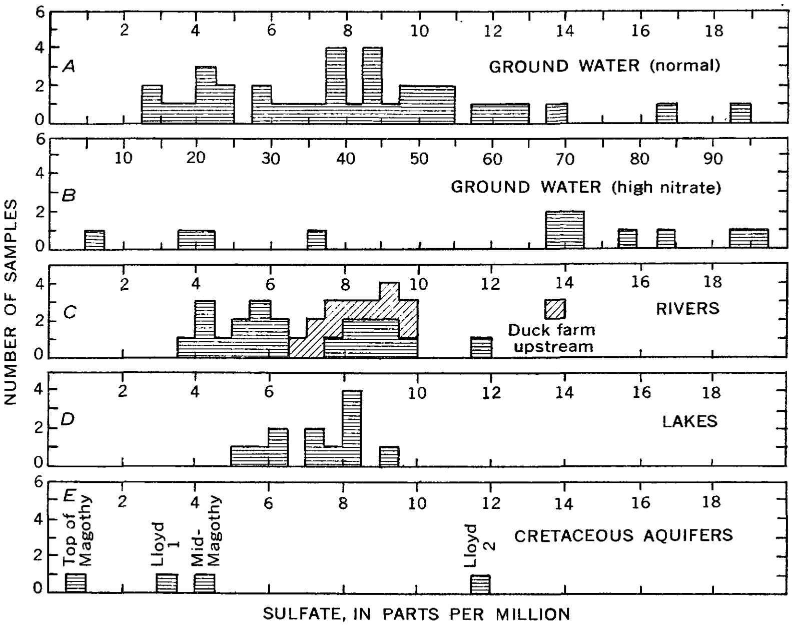

FIGURE 8.—Sulfate distribution, parts per million.

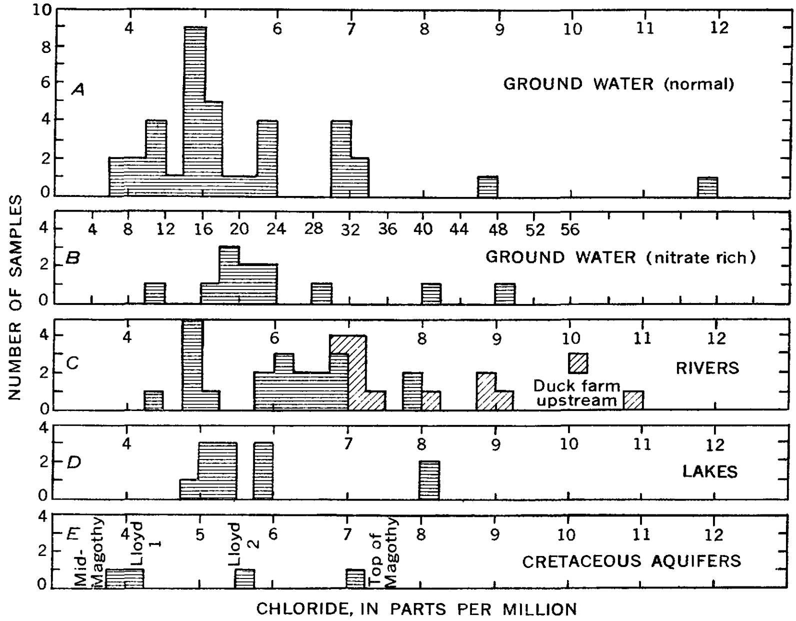

FIGURE 9.—Chloride distribution, parts per million.

under the discussion of sodium. A composite sample (collected by the writer) of all the rain and snow falling at the Laboratory, between March 31, 1952, and March 31, 1953, was found to contain 1.8 ppm chloride. This corresponds almost exactly to 1.0 ppm of sodium, using the chloride to sodium ration of sea water. The average chloride content of the samples of normal ground water was about 5.0 ppm, a figure also found for this area 50 years ago (Jackson, 1905, pl. 5). If one takes the figure of 1.8 ppm of chloride for the rainfall as valid, this would mean that the rain was concentrated by a factor of 2.7 due to evapotranspiration; or, to put this in a different form, if one starts with the average annual rainfall of 45 inches, 28.5 inches is lost by evapotranspiration, leaving only 16.5 inches of recharge. The ratio of evapotranspiration to recharge is probably more nearly one to one, and the average chloride and sodium contents of the rain, therefore, are more nearly 2.5 ppm chloride and 1.4 ppm sodium. There is some chance that the composite sample of rain and snow collected by the writer was not properly representative; the experiment, therefore, might be worth repeating.

The chloride content of the rivers ranged from 4.5 to 11 ppm, but almost all the samples containing more than 7 ppm of chloride were from points downstream from duck farms. The ducks appear to have added about 1 or 2 ppm of chloride to the streams in which they live. Even the duck-free streams averaged about 6.0 ppm chloride, however, as compared to 5 ppm for the ground water. There is no obvious reason for this. It is not due to any direct contamination by sea water.

The chloride content of the lakes ranged from 5 to 8.2 ppm and averaged nearly 6 ppm. As the dissolved-solids content of the lake water is less than that of the rivers or the ground water, in terms of percent of dissolved solids the lakes are distinctly chloride rich. In the samples analyzed the chloride, in fact, averaged 14.5 percent of the dissolved solids in the normal ground water, 14.2 percent of the dissolved solids in the river water, but constitutes 23.4 percent of the dissolved solids in the lake water. Several related factors are responsible for this. The chloride is virtually all in the rain as it falls. The rain that falls on the land is concentrated about two to one by evapotranspiration, so that its chloride content is roughly doubled. The rain that falls directly into the lakes, however, is concentrated by a factor of roughly three to one, as the average annual evaporation from the free-water surface of the lakes is estimated at about 30 inches. This rain, on the other hand, picks up little or nothing of other dissolved solids from the soil; therefore its contribution to the lakes is chloride rich but dissolved-solids poor as compared to the normal ground water. The lakes, however, also receive some direct surface runoff from the area immediately adjacent to them, and there is some ground-water movement into and out of the lakes with the rise and fall of the water table, so that the two types of water are mixed to some extent. Also, as a minor point, the low silica and iron content of the lakes make the chloride a slightly larger percentage of the total. The average dissolved-solids content of the lakes is slightly less than 30 ppm, whereas in the ground water it averages about 37 ppm.

NITRATE

The nitrate content of the samples of normal ground water ranged from 0.1 to 7.3 ppm, a variation nearly as great as that found in the iron content. The upper limit of nitrate in this group is perhaps arbitrary, as the natural ground water grades into the high-nitrate ground water. It may be that under natural conditions the upper limit of nitrate in the ground water would be around 2 to 4 ppm. The limit of the nitrate content of the normal ground water was set at about 10 ppm, only because where more than this much nitrate was found, there was clear evidence of contamination. The samples with between 4 and 10 ppm may be slightly contaminated, but there is little, if any, field or laboratory evidence to substantiate this. The average nitrate content of the samples of normal ground water was about 1.5 ppm; the mean value, about 0.5 ppm. The distribution of the amounts of nitrate found in the samples of normal ground water, and in the other samples, is shown on figure 10 in the form of a cumulated percent frequency plot on semilog paper, as was done for iron, because the range of values was too large to show clearly in a conventional histogram.

Unlike the iron, the nitrate content of the water from any one well is fairly consistent. Take, for example, five wells, all on the Brookhaven National Laboratory property. The 4 samples from S6405 (table 6) had either 0.1 or 0.2 ppm; the 5 samples from S3197 had either 0.2 or 0.5 ppm; the 3 samples from S5234 had either 0.6 or 0.8 ppm; the nitrate content of the 4 samples from S2485 ranged from 1.2 to 2.3 ppm, and the nitrate content of the 3 samples from well S3405 ranged from 2.7 to 7.3 ppm. The range of nitrate content in all these samples is from 1 to 73, and yet the range of samples from any one well is from about 1 to 2 or 1 to 3.

The nitrogen naturally present in the ground water is largely, if not entirely, picked up by the infiltrating rain in the soil zone. The soil gets nitrogen, of course, from the atmosphere, but the fixation of the nitrogen is a biological process. Plice (1932, p. 213) suggests that forest soils are low in nitrate, as trees are comparatively slow at nitrogen fixation, and that much higher quantities of nitrate are found in

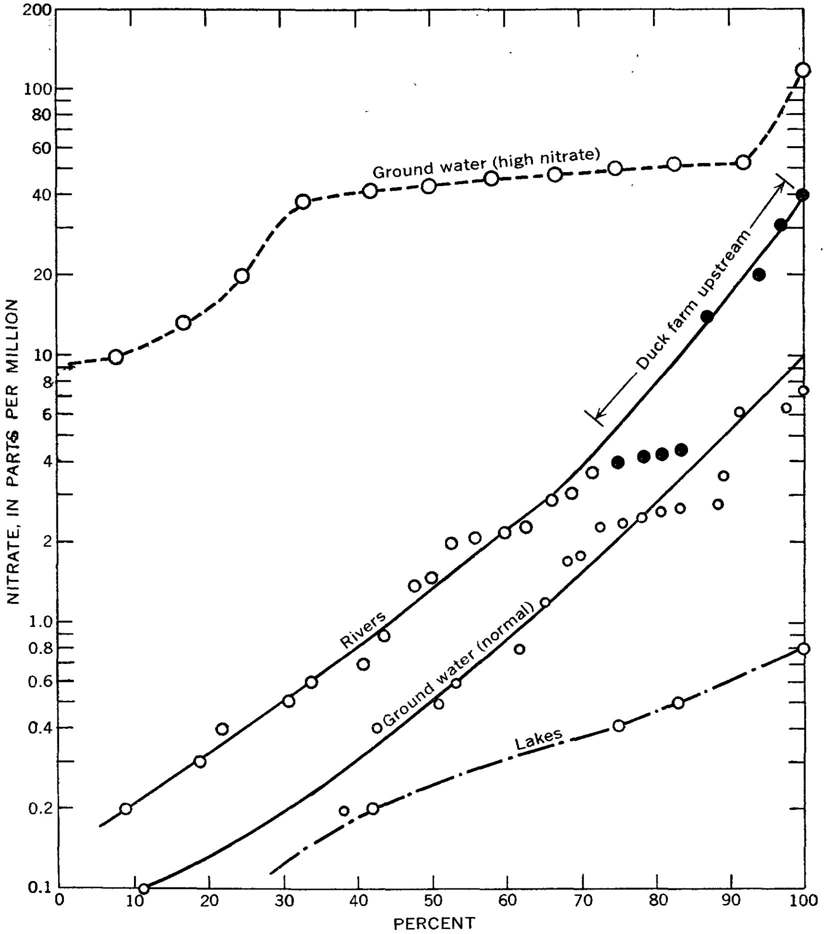

FIGURE 10.—Percent of samples having less than indicated amount of nitrate.

mucky soils and swamps. Such factors as these are perhaps partly responsible for some of the observed differences in nitrate content of the ground water.

The nitrate content of the river-water samples ranged from 0.2 to 40 ppm, although all samples with 4.5 ppm or more were taken from points downstream from one or another of the duck farms. The normal range of nitrate in the surface water is from about 0.2 to 4.5 ppm, very much the same range as that exhibited by the normal ground water. There can be little doubt that the duck farms contribute appreciable quantities of nitrate to the streams that flow past them. This question will be discussed more fully below.

The nitrate content of the lake-water samples ranged from 0 to 0.8 ppm. This low nitrate content reflects several factors. In the first place, the lake water receives an unknown, but probably significant, proportion of rain water and direct surface runoff that had very limited contact with the soil, and so contains only small quantities of nitrate. In the second place, the lakes, as it happens, are, in general, remote from sources of ground-water contamination. The shores of Lake Ronkonkoma are fairly well built up, but this lake is very near the water-table divide, and there is probably here a minimum of mixing of the ground water and lake water. A third factor that would tend to lower the nitrate content of the lake water is the growth of algae, for these plants extract nitrate from the water as they grow.

DISSOLVED SOLIDS AND SPECIFIC CONDUCTANCE

The dissolved solids are the residue on evaporation of a clear sample of the water. Some organic matter and water of crystallization will be included for many samples, although this seldom is of significance. Bicarbonate will be converted to carbonate, so that if a comparison with the sum of the determined constituents is desired, the amount of bicarbonate reported must be divided by 2.03. If the water contains appreciable quantities of calcium sulfate and chloride, the residue will contain water of crystallization, and its measured weight is likely to be greater than the sum of the weights of the individual components as determined by chemical analysis. In water containing magnesium carbonate, or unusually high nitrate, potentially volatile compounds are present; therefore the computed sum may exceed the weight of the residual solids measured after heating. The reader, therefore, should not expect to find in all samples a close agreement between the sum of the reported constituents and the dissolved solids, although the difference in general is not large.

The dissolved-solids content of the normal ground-water samples ranged from 26 to 59 ppm (fig. 11), but the distribution was not uniform. There were far more samples with about 30 ppm than there were with about 40, and there were relatively few samples with 50 ppm or more.

It is difficult to say just which ions are more concentrated in those samples of normal ground water with 50 ppm dissolved solids, as compared to those with 40, and similarly to define the differences between those with 40 and those with only 30. Table 2 summarizes what information is available. It was prepared by dividing the samples of normal ground water into three roughly equal groups on the basis of their dissolved-solids content and then determining the average concentration of each ion in each of these groups.

The following inferences may be drawn from table 2: silica, iron, sodium, and chloride do not increase as the dissolved-solids content increases from 26 to 50 ppm. On the other hand, calcium, magnesium,

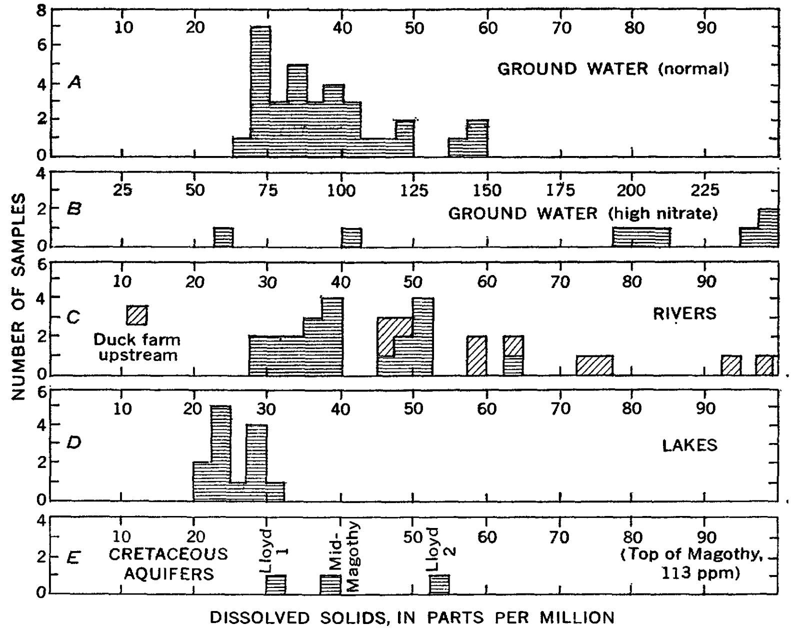

FIGURE 11.—Dissolved-solids distribution, parts per million.

potassium, sulfate, and nitrate do increase over this range, although not all of them in the same way. Nitrate, in particular, increases much more between groups 2 and 3 than it does between groups 1 and 2.

The range of the bicarbonate contents is less clear. The average bicarbonate content of group 2 is slightly less than that of group 1, but this is due to the low bicarbonate content of the four samples from well S6405, which all fall in group 2. The bicarbonate content

TABLE 2.—*Average composition of samples of normal ground water, grouped on the basis of dissolved-solids content*

	Group 1 26–32 ppm solids	Group 2 34–40 ppm solids	Group 3 41–59 ppm solids
Silica	7.8	7.9	7.7
Iron	.5	.9	.5
Calcium	1.8	2.3	4.9
Magnesium	1.2	1.4	2.1
Sodium	4.0	4.8	4.4
Potassium	.6	.8	1.8
Bicarbonate	8	7	12
Sulfate	5.2	8.8	9.5
Chloride	5.0	5.6	5.1
Nitrate	.3	.7	4.0
Dissolved solids (avg)	29	36	49

of group 3 is somewhat higher, but not strikingly so. Bicarbonate apparently contributes little to any general change in the dissolved-solids content of the normal ground water; it probably varies in concentration quite independently of all the other ions.

The concentrations of the cations—calcium, magnesium, and potassium—and of the anions—sulfate and nitrate—are probably related in some way to one another, and statistically, although not in individual samples, their concentrations increase or decrease together.

Even in comparing individual samples there is a close correlation between dissolved solids and specific conductance. This is shown by figure 12, in which the two are plotted against one another. The approximate relation may be expressed by the equation:

$$\text{Dissolved solids} - 8 = \text{specific conductance} \times 0.54$$

The ground-water samples, including the high-nitrate samples, and the river-water samples, also fit this relation fairly well (fig. 13). The lake samples, however, are better conductors than their dissolved-solids content would suggest, and the line along which the plotted lake samples fall on figure 12 passes through the origin, when extended. The difference between the dissolved-solids contents of the ground-water and river-water samples and that of lake-water samples is largely due to their silica contents. In ground-water and river-water samples, silica contributes about 8 ppm to the average weight of

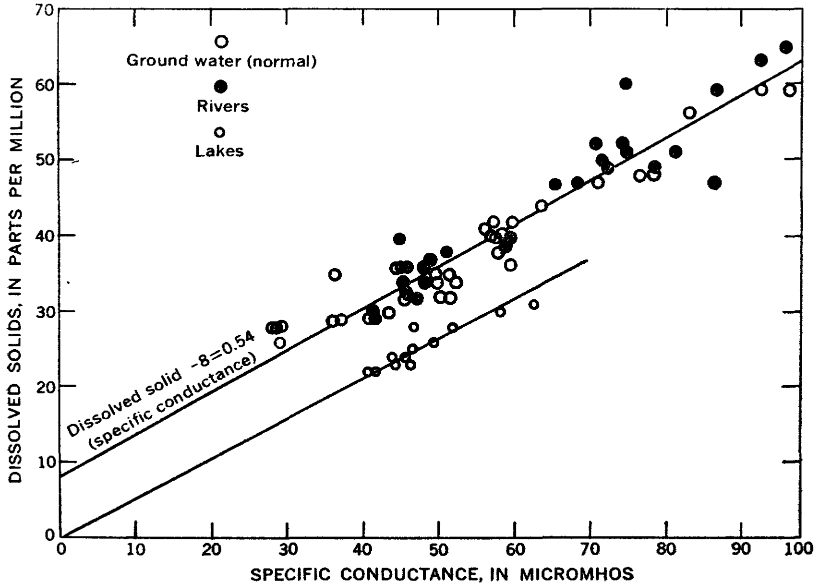

FIGURE 12.—Relation of dissolved solids to specific conductance in normal water.

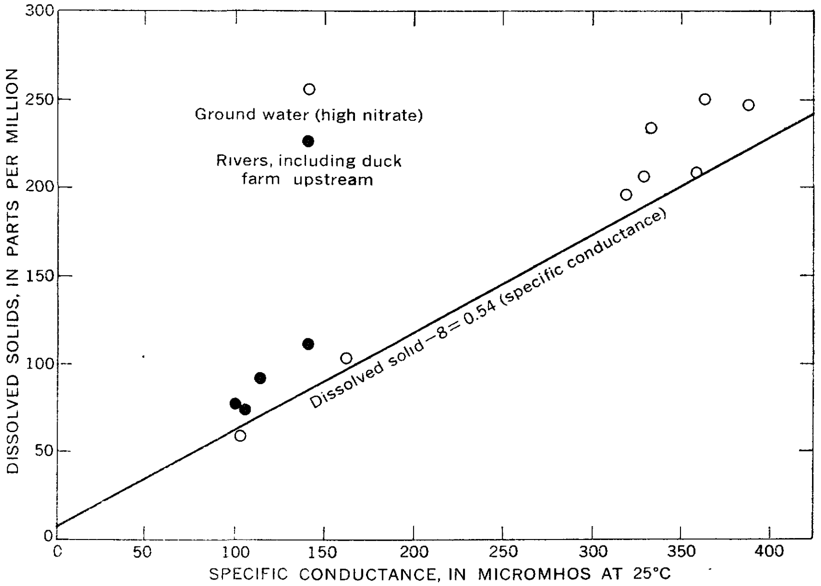

FIGURE 13.—Relation of dissolved solids to specific conductance in contaminated water.

dissolved solids but nothing toward the specific conductance of the water because the silica is not ionized. The lake water is almost free of silica.

pH

The pH of a water sample is not a quantitative measure of the alkalinity or acidity of the water, but is rather a measure of an intensity factor; that is, it indicates the concentration of hydrogen ion at any given time. Small quantities of strong, highly ionized acids or bases will have as great an effect on the pH as much larger quantities of weak acids or bases. Acids, bases, and the salts of a strong acid or base, combined with a weak base or acid, and chemical reactions which involve, directly or indirectly, any of these compounds, will all influence the pH of the sample.

As it happens, several of the more important compounds that help to determine the pH of the water samples described here are formed by, or are subject to, reactions with gases in the atmosphere, so that the pH of the water is subject to change if the sample is exposed to the air. Determinations of pH, therefore, are not easily reproducible, especially if the samples have to stand for some time before being tested, even if the container is tightly stoppered. For some of the samples tested at Brookhaven as part of the monitoring program, two readings were made: one on a fresh sample, and one on a sample that had been exposed to the air for at least a week and so had come to equilibrium.

In general, the most important changes in pH of a ground-water sample exposed to the air come about through loss of carbon dioxide. The air in the soil zone contains as much as 1.5 percent CO_2, the atmosphere contains only 0.03 percent. The ground water in soaking through the soil picks up more CO_2 than it had as rain, and the immediate effect of this is to increase the carbonic acid in the water and lower its pH. The carbonic acid meanwhile reacts with the mineral grains in the soil and rock and is the principal agent, in fact, in their decomposition. The products of this attack include sodium, calcium, magnesium, potassium, and bicarbonate ions. Bicarbonate ions tend to make the water alkaline. In other words, the carbon dioxide makes the water acid, but some of the ions that form during solvent action of water on the soil tend to make the water alkaline. The result is that a typical sample of ground water that might have a pH of 6.0 when freshly pumped out of a well might change to 7.2 on standing due to loss of carbon dioxide. Distilled water in contact with the air picks up enough carbon dioxide from the minute quantities in the atmosphere to have a pH of about 6.3. The difference between 6.3 and 7.2 is largely due to the bicarbonate in the natural water. The difference between 7.2 and 6.0 is largely due to the larger quantities of carbon dioxide in the fresh ground water, which escaped on standing.

Other reactions can influence the equilibrium between carbon dioxide, carbonic acid, and bicarbonates on which the pH of the water so largely depends. The oxidation of ferrous iron to ferric iron increases the valence of the iron, and so increases the amount of hydroxyl ion that is bound up with it as hydroxide. Therefore, as the iron oxidizes, it must extract hydroxyl ion from the solution, leaving hydrogen ions free, which lowers the pH of the solution. The oxidation of other cations might produce a similar result.

The pH of surface-water samples changes somewhat if they are stored partly because the water in the streams is not in complete chemical equilbrium with the air, and partly, perhaps, because of temperature changes, which affect the solubility of carbon dioxide in the water. The pH of lake-water samples change even less than stream-water samples, and the changes in the surface-water samples in general are less than half of those in the ground-water samples.

The pH of the surface water is, however, subject to some extraneous influences. The pH of the sample collected from the Carmans River at Route 27 on June 6, 1951, was 9.3. Subsequent water samples from this point were similarly alkaline until the middle of September, when their pH started to drop. By October 3 it had decreased to 6.9. All this time the pH of the river upstream from the ponded sections had continued to have a normal pH of about 6.0. This high pH may be the result of an unusually heavy growth of algae in the ponded sections of the river in 1951. A rapid growth of algae would use up the carbon dioxide in the water and increase the pH by causing a shift to the right in the following equilibrium:

$$\underset{\text{(weak base)}}{2HCO_3^{-1}}=\underset{\text{(active base)}}{CO_3^{-2}}+H_2O+CO_2$$

In 1938 the pH of this same downstream point on the Carmans River was 8.6, according to the Division of Fish and Game, New York State Department of Conservation.

Another group of reactions which apparently affect the pH of a few of the water samples involve the nitrogenous products released by sewage. In these products ammonia is relatively rich in the early stages, but it is later oxidized to nitrites and then to nitrates, with a consequent drop in pH. Sampling at the Brookhaven National Laboratory's sewage-disposal plant showed that the raw sewage had a pH of 7.1 to 7.2, which dropped to 6.8 and 7.0 in the Imhoff tank, to 5.4 after filtration at the chlorine house, and to 4.7 at the east boundary of the Laboratory a half mile downstream along the Peconic Ditch. Similarly, special sample 1, which was taken directly from a small cesspool, had 402 ppm of NH_3 and a pH of 7.5, whereas the samples from well S9144, the Brookhaven Town Police Station at Center Moriches, suspected of being cesspool contaminated, had pH's on the order of 4.7 to 4.8. These last samples on standing changed to a pH of 4.4 to 4.5 and were the only ones which became more acid on exposure. Organic acids formed by oxidation of the sewage are probably responsible for values of pH below 5.5.

It appears, therefore, that the pH of the water samples, simple as it may appear by definition, is actually the resultant of a complex of factors, some related and some quite distinct. Any interpretation of the reported values of pH, therefore, must be made very cautiously, unless there is adequate independent data to substantiate the suggested conclusions.

The pH of the samples of normal ground water analyzed in Washington ranged from 5.1 to 6.9, although only 2 samples had a pH of less than 5.5 (fig. 14). Reference to the additional values obtained at Brookhaven tends to confirm the impression that the normal range in pH for the ground water is from about 5.5. or 5.7 to about 7.0. The range in values for the samples from any one well is generally less, and the values obtained from the determinations made at Brookhaven

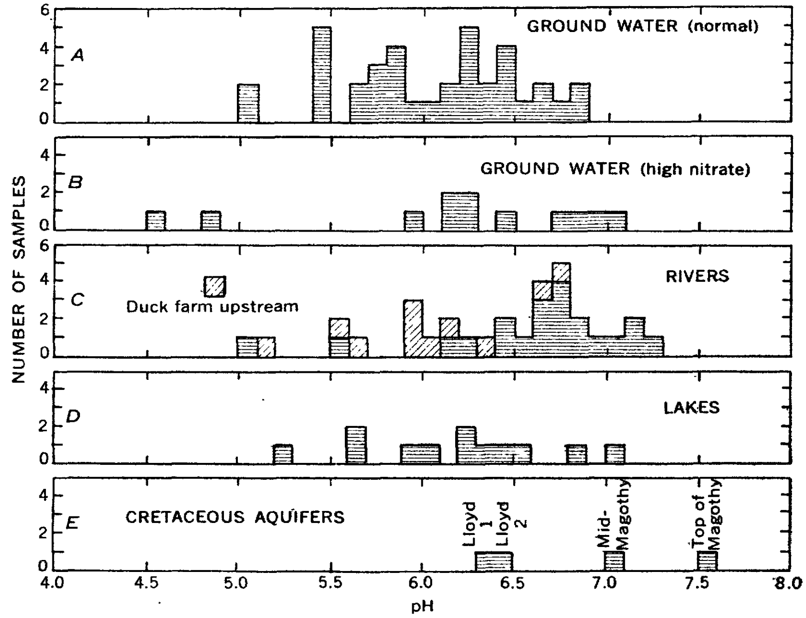

FIGURE 14.—pH distribution.

appear to be somewhat more consistent than those obtained in Washington, where more delay before analysis was inevitable.

A few wells, notably S6405, consistently yield samples with a low pH; in these samples the pH ranged from 5.5 to 4.8 and averaged about 5.2. This is the same well that produced samples so unusually low in bicarbonate, and without doubt these are two manifestations of the same peculiarity of this well. The water from this well is unusual in no other way, and no explanation can be offered.

The pH of the river-water samples ranged from 5.1 to 7.3, but in most samples, was between 6.0 and 7.0. Almost certainly the streams are, in general, slightly less acid than the ground water. The obvious explanation is that the streams contain less CO_2, as they are more nearly in equilibrium with the atmosphere, although other factors are certainly present. The samples taken downstream from duck farms were slightly more acid than the others, but the data are not sufficient to be reliable.

The pH of the lake-water samples, as analyzed in Washington, ranged from 5.3 to 7.1. The tests made at Brookhaven gave somewhat less variable results. The pH of the lakes is probably similar to that of the rivers, although the data are not sufficient to establish the relation.

The sample collected from the Peconic River at Calverton on March 29, 1949, was reported as having a pH of 4.25. A second sample collected August 1, 1949, had a pH of 5.6. The first sample represents either some as yet unidentified temporary condition, or an error was made in the sampling.

MINOR CONSTITUENTS

For most of the samples, in addition to the tests the results of which are described above, determinations were also made of the content of fluoride, aluminum, phosphate, copper, and zinc. No graphs have been prepared to show the distribution of the amounts of these materials in the samples, but an inspection of the results suggests the following generalizations.

The streams and lakes are a little richer in fluoride than the ground water. A little more than half of the surface-water samples had 0.1 ppm fluoride or more, and the maximum was 0.4 ppm. A little more than a third of the ground-water samples had more than 0.1 ppm fluoride, and the maximum was 0.2 ppm. The fluoride content showed no obvious relation to any of the other constituents or properties of the water samples, except that the highest fluoride content was found in some of the samples taken at points downstream from one or another of the duck farms. This high fluoride content may be due to the high phosphate content of these samples, which interferes with the determination for fluoride. Except for this, no well or surface-water sampling point appeared to be consistently fluoride rich or fluoride poor, and there is no explanation for the differences between samples.

The aluminum content of the samples varied from 0 to 1.7 ppm in what appeared to be an entirely erratic manner, and the variations in successive samples from the same place were as great as the variations between localities. In general, the ground-water samples had the most aluminum and the lake-water samples the least. The sample from the Peconic River at Calverton, collected March 29, 1949, was reported as having 2.2 ppm aluminum, but this is the same sample reported to have a pH of 4.25, a value so low that the sampling itself is suspect.

Most of the samples had less than 0.1 ppm phosphate, the smallest amount that could be reliably measured, and, except for the river samples, the highest value reported was 0.3 ppm. The stream samples taken directly below a duck farm had as much as 5 to 8 ppm phosphate, a concentration obviously attributable to the ducks. It is interesting to note that the nitrate-rich ground-water samples did not contain increased amounts of phosphate, although the cesspool effluent contains appreciable amounts, and it is one of the principal ingredients of commercial fertilizer. This is because the phosphate added to the soil is rapidly converted to an insoluble form which cannot be taken up by the water. New phosphate is added, not because the old phosphate has been leached out or used up, but rather because it has become fixed in the soil and cannot be picked up by the soil moisture.

Copper and zinc were found in only a few of the water samples. One of the surface-water samples was reported to have 0.1 ppm copper; none of them were reported to have any zinc. In the ground-water samples, the zinc in particular was found in the small diameter wells cased with galvanized pipe, but not in the wells cased with uncoated steel casing. There is no doubt in the writer's mind that the zinc represents contamination from the well, although more than three times the volume of water in the well was run to waste before any sample was collected. If the relatively inert zinc can so contaminate the water in a well, there is all the more reason to be suspicious of the determinations of iron made with samples from wells cased with iron pipe.

In 1949 a special test for hydrogen sulfide was run on a water sample from well S7204, an irrigation well 50 feet deep located northeast of Lake Panomoka (Long Pond). This well had been drilled in the bottom of a small kettle hole in order to make the distance to water short enough to use a centrifugal pump. The water had a distinct odor of hydrogen sulfide, and analysis showed the presence of nearly 1 ppm of this gas in a fresh sample. The kettle hole, originally deeper, may have had a swamp or shallow lake in it at one time. As the depression filled in, considerable vegetation must have been buried, and its decomposition is suspected of being the source of the hydrogen sulfide noted. This is a purely local phenomenon and does not seem to have interfered with the use of the water for irrigation.

TEMPERATURE

Figure 15 shows the observed distribution of temperature in the two deep wells drilled on the Laboratory tract. These values may be slightly influenced by convection currents in the wells, but as identical readings (not shown) were found in the 4-inch well S6455 and in the neighboring 10-inch well S6434, the influence of convection is probably not important. The readings were made during the winter by lowering a pressure-sealed maximum-reading thermometer into the well, and each value so obtained was found to be reproducible to less than a tenth of a degree.

The water is slightly cooler at the base of the upper Pleistocene aquifer, just above the Gardiners Clay, than it is at the water table. It appears unlikely that density differences are responsible, and no explanation can be advanced. Many readings were taken, and the curve (fig. 15) represents the actual conditions. Below the Gardiners Clay the temperature rises at a rate of about 1°F per hundred feet, and the temperature gradient is slightly steeper where the well passes through the heavy clay member of the Raritan Formation.

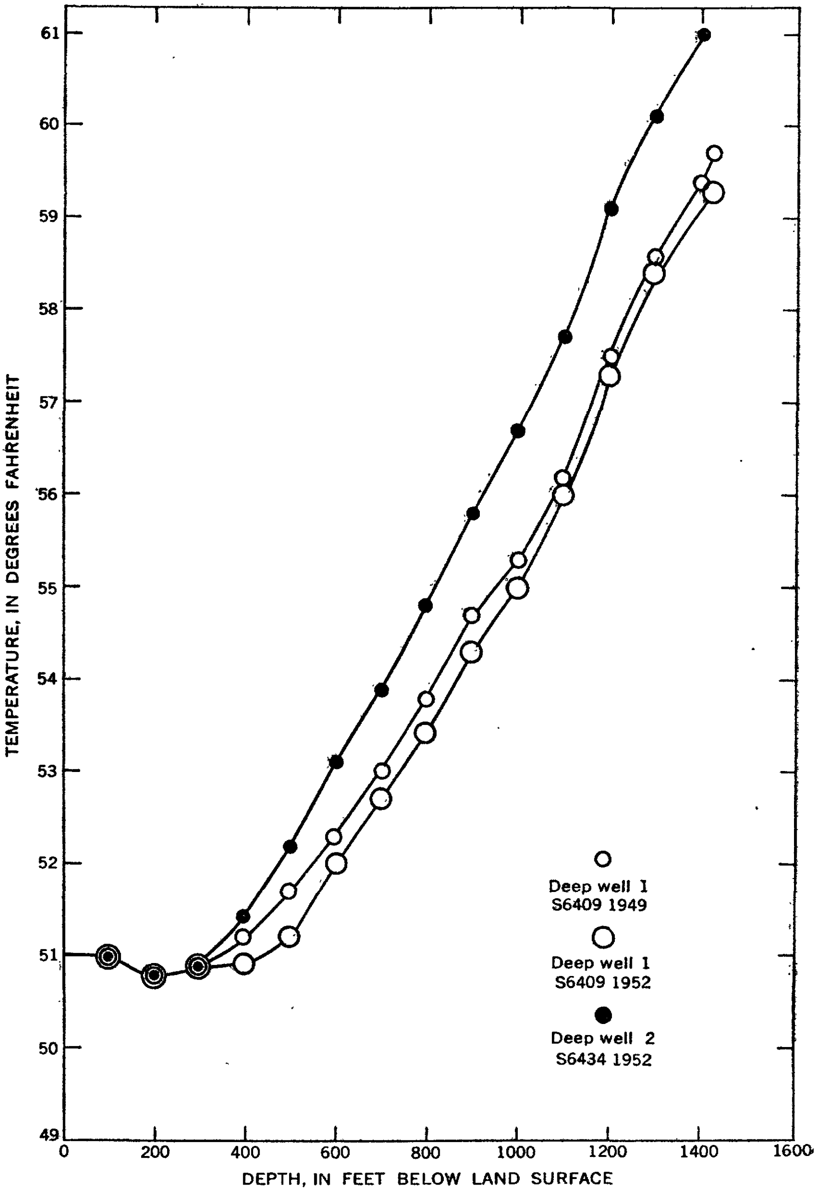

FIGURE 15.—Geothermal gradients, Brookhaven National Laboratory, N.Y.

WATER SAMPLES FROM THE CRETACEOUS ARTESIAN AQUIFERS

There are four analyses of samples of water from the Cretaceous aquifers. Obviously, no proper study is possible with so little data, but a comparison with the water samples from the glacial outwash sands shows certain points of interest.

Well S6456 was screened in the top of the Magothy(?) Formation at the time the sample was pumped with an air lift. The immediately overlying Gardiners Clay, and the associated greenish sands, contain some glauconite and shell fragments, and it is this material, in all probability, that is responsible for the high calcium (19 ppm) and high bicarbonate (80 ppm) content of the water sample. The high silica content (33 ppm) may be a secondary effect resulting from the high bicarbonate and pH (7.6), as silica is somewhat more soluble in alkaline solution. The sample is also unusual in containing only 0.9 ppm sulfate. The possibility that wells screened just below the Gardiners Clay can be identified by a chemical analysis of the water from them is of some interest, because the Cardiners Clay is one of the key stratigraphic markers on Long Island, although it is not always possible to identify it in well logs. Water with this slightly higher bicarbonate content and pH would probably be less corrosive than the normal ground water, which, because of its low content of metallic bicarbonates, slightly acid pH, and free carbon dioxide, is sufficiently "aggressive" in many areas to attack plumbing at an annoyingly rapid rate.

The first sample pumped from well S6434 came from a sandy zone at a depth of about 675 feet, near the middle of the Magothy(?) Formation. It is very similar to the normal ground water in the glacial sands, although it is slightly richer in calcium and silica than the average of the normal ground-water samples, and contains more bicarbonate than all but a very few samples. It is also slightly richer in silica than any of them, but the difference is not very marked.

The second sample from well S6434 and the sample from well S6409 came from the Lloyd Sand Member of the Raritan Formation. The two samples are somewhat similar to one another, and they also closely resemble the normal ground water. Both are, however, a little higher in the sum of their calcium, magnesium, sodium, and potassium ions than the average of the water from the glacial sands, but it is only in their higher bicarbonate content that they show any significant difference.

HIGH-NITRATE GROUND WATER

IDENTIFICATION OF CAUSES

The high-nitrate ground water was defined as that containing more than 10 ppm of NO_3, but it not only contains more nitrate than the normal ground water, it is also richer in calcium, magnesium, sodium, potassium, chloride, and sulfate. The two groups contain virtually identical amounts of silica, bicarbonate, phosphate, fluoride, copper, and zinc. The high-nitrate ground-water samples may also on the average contain somewhat larger amounts of iron, but on this point the data are not conclusive.

The nitrate in normal ground water is generally believed to be picked up in the soil zone where nitrogen from the air is fixed by biologic processes. These processes depend on the nature of the soil and vegetation, and in consequence the normal nitrate content is variable; but in the absence of contamination it seldom exceeds 3 or 4 ppm in acquifers like those on Long Island (Norcom, 1938). The limit of 10 ppm nitrate is probably somewhat high and some of the samples classed as normal ground water are probably slightly contaminated, but not sufficiently to make a clear conclusion. Before discussing the origin of the contamination, however, the composition of the high-nitrate water will be more fully described.

The amount of silica in the high-nitrate ground water ranged from 6.9 to 13 ppm, slightly higher than in the normal ground water, although the difference is hardly large enough to be significant considering the small number of samples tested.

Iron was determined in only eight samples of high-nitrate ground water, too small a number to be the basis for valid generalization. There was a suggestion that these samples were somewhat richer in iron than the normal ground water, but, as will be indicated below, the high-nitrate ground water is somewhat more corrosive than the normal ground water, and the slightly higher iron content of the eight samples may come from the sampling wells, despite care to pump them clear before sampling. There was also no apparent increase in the bicarbonate in the samples of high-nitrate ground water, and there was no reason to doubt the validity of these data.

The high-nitrate ground water is much richer in both calcium and magnesium than is the normal ground water. The calcium content ranged from 3.6 to 45 ppm as compared with 1.0 to 7.6 ppm; the magnesium content ranged from 3.1 to 8.3 ppm, as compared with 0.6 to 3.6 ppm. The increase in calcium was most marked in those high-nitrate wells that appear to be contaminated by the leaching of fertilizer.

The sodium content of the high-nitrate ground-water samples ranged from 7.9 to 29 ppm, as compared with 3.2 to 6.3 ppm for the normal ground water; the potassium content ranged from 1.2 to 4.8 ppm as compared with 0.4 to 2.0 ppm for the normal ground water.

The chloride and sulfate anions are also much more concentrated in the high-nitrate ground water. The chloride content ranges from

12 to 80 ppm, as compared with 3.8 to 8.9 ppm in the normal ground water; the sulfate, from 6.4 to 96 ppm, as compared with 2.6 to 19 ppm. There was no apparent increase in the phosphate in the high-nitrate ground water.

The high-nitrate ground-water samples were in general somewhat less acid than the normal ground-water samples, although the data are not sufficient to confirm this impression. Two of the high-nitrate samples had very low pH's—4.6 and 4.9. One of these is almost certainly the result of cesspool contamination; the other may be also. Contamination from commercial fertilizer does not appear to affect the pH of the ground water.

The geologic environment of the wells yielding the two types of ground water is identical, so that there is no reason to believe that the differences can be explained by natural causes. On the other hand, nitrates in ground water have commonly been attributed to contamination by sewage, and somewhat less commonly, to the leaching of commercial fertilizer, although for the latter cause, little quantitative information is available (Foster, 1949, p. 654).

The first well in which an abnormally high nitrate content was noted was S5341, located at the Long Island Vegetable Research Farm north of Riverhead in the heart of an area of intensive potato farming. The suggestion of cause and effect appeared obvious here, because the potato fields are heavily fertilized. As a basis of comparison, water samples were then collected from private wells in areas of long-established potato farming in eastern Suffolk County at East Marion, Southold, Cutchogue, Mattituck, Riverhead, East Hampton, and Sagaponack. All these samples were found to contain between 20 and 120 ppm nitrate, with an average content of about 40 ppm. Subsequent work, although still fragmentary, has confirmed the impression that in all the areas devoted to potato farming, the ground water contains on the order of 40 to 50 ppm nitrate. The high-nitrate samples in the nonfarming areas will be discussed below.

Rough computations show that the fertilizer is quantitatively capable of supplying the nitrate observed in the ground water. A typical acre of a Suffolk County farm is treated each spring with about 1¼ tons of fertilizer containing 125 pounds of nitrogen, or about 550 pounds of nitrate. Intensively cultivated fields receive more. The weight of water per acre that infiltrates down to the water table in an average year is about 5,000,000 pounds, so that if this water dissolved out all the nitrate, it would contain 110 ppm of nitrate. A complete inventory of the nitrate would have to consider other factors, but the other increments and losses of nitrate are relatively minor. A point worth considering, however, is the recycling of nitrate by irrigation. Our hypothetical average acre may receive 2 million pounds of irrigation water even in a normal year, and if this water contained 40 ppm nitrate, it would bring in an additional 80 pounds of nitrate, or roughly, 15 percent of the nitrate added directly. Virtually all the irrigation water is lost to the soil by evapotranspiration, so that the process of irrigation serves further to increase the nitrate content of the ground water. In areas like Southold on Orient Point, where the island is narrow, irrigation also serves to lower the natural gradient of the water table and so slow down or even stop the movement of the ground water out from under the island to Long Island Sound and Peconic Bay. Under these circumstances the concentration of nitrate and of other ions in solution in the water could increase considerably beyond the values so far noted.

The composition of the fertilizer used for potato and cauliflower farming varies with the grade and the mix, but common ingredients are calcium, sulfur, phosphate, dolomite ($CaMg(CO_3)_2$), magnesium oxide, sodium nitrate, ammonium sulfate, and, for side dressing, potassium chloride. The potato fields are usually kept slightly acid, with a pH in the neighborhood of 5.5, to inhibit the growth of the actinomyces that produce potato scab, and powdered sulfur may be used for this purpose. The most common accessory ingredients, apart from the true fertilizer elements of nitrate, phosphorus, and potassium, are calcium and sulfate. The most variable in quantity are probably sodium and chloride. In other words, the fertilizer contains those very ions which are found in increased amounts in the high-nitrate type of ground water.

Three wells yielding water in the high-nitrate group are in areas where contamination by fertilizer is impossible or improbable. The outstanding example is S9144, which supplies the Brookhaven Town Police substation in Centre Moriches. Although there are a few gardens and small cultivated fields outside town in this general area, this is not a farming community, and not enough fertilizer is used to account for the observed effect. The chemical contamination undoubtedly comes from one or another of several nearby cesspools, although uncertainty as to the direction of movement of the ground water in this area prevented identification of the source. Much the same can be said for well S2815, also in Centre Moriches, although in this well the contamination is less marked.

The third well, S742, supplied the writer's home. In the summer of 1952 a new cesspool was constructed directly south of the well and about 50 feet from it. The location was chosen to avoid digging up a path, driveway, and shrubbery, although with some misgivings, as it is obvious that the ground water here is moving due north to Long Island Sound. One mitigating circumstance is that the depth to water here is about 80 feet. Within 4 or 5 months the water from this well began to be rusty, and the sample in table 6 shows the composition of the water about 9 months after the cesspool was put into use. Partial analysis made at Brookhaven showed that by the summer of 1953 the nitrate and chloride content of the well had each reached 30 ppm. At about this time the cesspool south of the well was abandoned and another new one was dug some yards to the east. In March 1954 the nitrate content of the water was down to 10 ppm and the chloride was down to 14 ppm. Throughout this period several neighboring wells had no detectable nitrate and only 8 to 10 ppm of chloride.

Although it did not appear appropriate to the present study to attempt to go into the question fully, a little further work was done as follows: Special sample 1 was prepared by filtering about 2 gallons of distilled water with which had been mixed about 3 gallons of moist soil dug from the top of a field which had been cultivated to potatoes for many years. The soil was collected in the early spring just before planting time and might, therefore, be expected to contain a minimum of dissolved solids for such a sample; but the filtrate, in a rough way, may be taken to represent the mineral content of the water that reaches the water table in areas of intensive farming. Special sample 2 was taken from the writer's cesspool; that is, the one which contaminated well S742. The sample probably is reasonably typical of cesspool effluent, although obviously before reaching the well the effluent must undergo various chemical changes in the soil, particularly the oxidation of the ammonia to nitrite and then to nitrate. A comparison of these two samples suggests the following: The leaching of the fertilizer produces calcium sulfate as the predominant component, in addition to the nitrate, whereas the cesspool effluent contains a larger relative proportion of sodium chloride. Examination of the analyses of samples from cesspool and fertilizer contaminated wells bears this out (table 3).

Out of curiosity, samples from two of the supply wells of the community of Levittown, some 40 miles west of the Brookhaven National Laboratory, were tested. This town, noted for the low-cost mass production of its houses, was built on what previously had been farmland. The area did not then have sanitary sewers, and each house had its own cesspool. When the high nitrate content of the ground water was first noted by health authorities, it was attributed to cesspool contamination, and was for a time a matter of some concern. Our analyses, however, show the water to be high in calcium sulfate rather than sodium chloride, suggesting that fertilizer was the source of the nitrate in the ground water.

The cesspool effluent is probably quantitatively sufficient to supply the nitrate observed in the water, if sufficient time were available for the concentration to build up. The amount of nitrogen excreted per

TABLE 3.—*Comparison of analyses of samples from fertilizer- and cesspool-contaminated wells*

	Wells		
	Long Island Research Farm S5341, Fertilizer-contaminated well	Police Station, Town of Brookhaven S9144, Cesspool-contaminated well	Levittown N2403
	Parts per million		
Calcium	29	18	45
Sodium	17	29	15
Magnesium	8.1	5.7	7.3
Potassium	2.7	4.4	2.6
Nitrate	43	52	46
Chloride	20	50	22
Sulfate	72	20	96
Bicarbonate	9	3	9
Dissolved solids	206	208	247

day by an adult is somewhat variable, but 20 grams per day is a probable average value (Bodansky, 1938, p. 454). Levittown has a population density of about 16 people to the acre, which would give a nitrate yield of 320 grams per day, or 1,135 pounds of nitrate per year per acre of built-up land. This is more than the 550 pounds of nitrate calculated as the probable annual contribution from fertilizer, but some allowance has to be made for service and recreational areas, and also for the comparatively limited extent of Levittown as compared to the unbroken miles of potato fields. Perhaps all one can say is that a community like Levittown probably can contribute about as much nitrate to the ground water as a similar area of farmland.

SIGNIFICANCE AND IMPORTANCE OF HIGH-NITRATE GROUND WATER

Fertilizer and cesspool contamination of the ground water obviously as such are not questions of direct concern to the Brookhaven National Laboratory. They are, however, an important aspect of the chemical quality of the ground water of Suffolk County, and, therefore, have a place in any comprehensive scientific discussion of this subject. The contamination which they represent is also a matter of some practical importance to the people of this area, and a brief discussion of this significance is appropriate, if this report is to have the broad scope described in the introduction. It should not be necessary, however, to apologize for including an account of the problems arising from the present chemical contamination of ground and surface water, in a report intended, among other things, to explore the possible complexities that might arise in the event of a future more serious contamination by radioactive materials.

The first point to consider could be, but is not yet, the most serious. The high-nitrate ground water, in some areas, appears to have reached a concentration of nitrate capable of inducing methemoglobinemia (a deficiency in the oxygen carrying capacity of the blood) in infants under 6 months of age, if they are fed with a milk formula prepared with this water. Children older than 6 months and adults are not affected. When this possibility was brought to the attention of the Suffolk County Department of Health, a search of their files, and a circumspect survey of some of the local physicians, showed no record or suggestion of any methemoglobinemia in Suffolk County. There have been many papers on this general subject, but the consensus appears to be that 44 ppm (as NO_3) should be regarded as unsafe for infant feeding (Maxcy, 1949), and that 220 ppm of nitrate will certainly cause methemoglobinemia in at least some of the more susceptible babies (Robertson and Riddell, 1949). In the Southold area concentrations of 50 to 100 ppm of nitrate are common, and because of the small part of the total area that has been examined, it is probable that higher values exist in a few wells. It is also in this area that the use of irrigation wells has reduced most importantly the natural rate of movement of the ground water, so that there is every probability of a continuing increase in nitrates. In that event it is only a question of time until some infants are affected by the water.

The second significant point about the high-nitrate water is its much greater corrosiveness as compared to the normal water. This was brought rather directly to the writer's attention when his own well was contaminated; in this well the water turned rust colored. Enough members of the Brookhaven staff have informally sought advice about similar problems so that it is clear that this is a fairly common circumstance. To test this the following experiment was made.

Water samples were collected from each of six wells, known or suspected of being contaminated, and from one well known to furnish typical normal water. Table 4 shows partial analyses. Fifty milliliter samples of each were put in 100-milliliter volumetric flasks, and an eighth flask was similarly half filled with distilled water. To each flask was then added a 10-penny iron nail that had previously been carefully cleaned by sandblasting, and then weighed. The 8 flasks, without their stoppers, were then shaken by machine, first for 1 hour and then for 15 hours more. At the end of the first hour the nails, most of which showed some signs of heavy tarnish, were removed, dried, and weighed again. The gain of weight in milligrams represents the oxygen taken up by the iron to form the tarnish coating. At the end of 16 hours of shaking, the attack on the nails in most flasks had produced a rather different result, as far too much oxide had been formed to remain on the nails, and it had washed loose

TABLE 4.—*Corrosion test*

[10-penny nails (weight 5 grams) were exposed to water contaminated by fertilizer or cesspools]

Sample	Contaminated by	Cl^- (ppm)	NO_3 (ppm)	Specific conductance (micromhos at 25° C)	pH	Gain(+) or loss (−) in weight, in milligrams	
						After 1 hr	After 16 hrs
1 (S742)	Cesspool	21	10	152	6.85	−0.2	−28.8
2 (W. Martin Southold)	Fertilizer	11	15	192	6.65	+.3	−50.5
3 (S. Macksel, Riverhead).	do	20	10	228	7.30	+.4	−40.5
4 (S5341)	do	22	45	344	7.15	+.4	−42.3
5 (S9138)	Fertilizer and possibly also cesspool.	52	70	587	4.83	+1.8	−45.1
6 (S9144)	Cesspool	38	80	377	4.60	+2.9	−41.6
7	Distilled water	0	0			−.3	−.1
8 (S6405)	Normal ground water	9	0	57	7.05	+.3	+.5

and was free in the water. This time when the nails were removed they were washed gently with a solution of oxalic acid to remove any remaining oxide, and then dried and weighed for a third time. The corrosiveness of the water is measured by the gain in weight after 1 hour and the loss in weight after 16 hours. Such a test, where the attack is accelerated by abundant oxygen and shaking, is not a proper basis for a quantitative comparison of corrosion rates, but it does suggest qualitatively the practical problems to be expected when using the high-nitrate ground water as a water supply.

The third topic to be discussed in connection with the high-nitrate water is the contamination of some of the streams and south shore bays by duck farms. This contamination contributes nitrate, phosphate, and other materials to the streams, and through them to the south shore bays. The work of the Woods Hole Oceanographic Institution (Redfield, 1950, 1952) has shown that this nitrate and phosphate are responsible for greatly promoting the growth of a green algae resembling the *Chlorella*, and locally called the "small forms," which, being plants, find the nitrogen and phosphorus essential to their growth. Under the stimulus of the increased concentration of these elements the algae have so increased in the past few decades as to make the water of the bays highly turbid, and therefore have greatly reduced the value of these bodies of water for many commercial and recreational purposes.

The algae require nitrogen and phosphorus in a ratio of about 15 to 1, the duck farm wastes supply these elements in a ratio of about 3.3 to 1; that is, the duck farm wastes supply a mixture which, for the growth of *Chlorella*, is overrich in phosphorus, so that nitrogen is the element in critical supply. In fact, in the summer, when the Chlorella "bloom" is widespread, there is no free nitrogen in the bay water; it is all bound up in the plant cells, as is much of the phosphorus. There is, however, considerable phosphorus also present in solution in the water. "The fact that nitrogen and not phosphorus is the limiting factor in the growth of algae in the bay should be considered in any attempt to reduce the pollution. Partial removal of phosphorus from the wastes may have no effect, whereas any reduction in nitrogen will be directly effective." (Redfield, 1952, p. 10.)

There are, however, two additional facts to be fitted into this picture. One is that the ground-water moving into the south shore bays brings with it a quantity of nitrogen derived from cesspools and fertilizer approximately equal to the total contribution by the duck farms. The average adult, as we have seen, excretes about 70 pounds of nitrate a year. About 100,000 people live (1954) in the area from which the ground water flows into Moriches Bay or Great South Bay; their total nitrate contribution, therefore, is roughly 7 million pounds or 3,500 tons a year, as compared to an estimated 2,200 tons a year from the ducks. The nitrate from the duck farms is largely released into a small area centering around Terrell River just east of Center Moriches, and largely during the 4 warmest months. The nitrate transported by the ground water is more evenly distributed in time and space, and is, therefore, less effective, pound for pound, in contributing to the summer growth of algae. Because of the slow movement of the ground water, the increase in population of the last few years has not yet made itself fully felt in the amount of nitrate reaching the bays. There is very little farming in the area contributing ground water to these bays, so that the amount of nitrate contributed by fertilizer is negligible.

Although the duck farms are not the only source contributing nitrate to the bays, they are the only important source of phosphate. Our own observations and those of others (Bizzell and Lyon, 1928) show that phosphate does not reach the ground water either from fertilizer or cesspools, but is trapped by the soil. The analysis of the streams below some of the duck farms, however, shows a sharp rise in phosphate, and the Woods Hole study also makes clear that considerable phosphate from the duck farms must reach the bays. It would be very difficult to prevent the movement into the bays of the nitrate from the many cesspools in the area, and, to judge from the relative mobility of the compound, very difficult to permanently prevent the nitrate from the duck farms from also reaching the bays. If the phosphate now reaching the bays from the duck farms could be prevented from doing so, which may well prove feasible, this might be sufficient to restrict the growth of the algae in the bays, so that the movement of the nitrate would be immaterial.

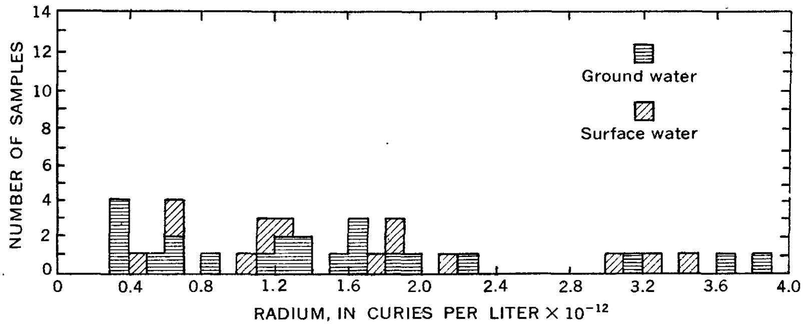

FIGURE 16.—Radium distribution, curies per liter $\times 10^{-12}$.

NATURAL RADIOACTIVITY OF THE WATER SAMPLES

The National Bureau of Standards made determinations of the radium content of 27 of the ground-water samples and 10 of the surface-water samples from the group of about 100 on which the Geological Survey made chemical analyses. As radium probably is the principal source of natural activity in the water, these values may also be taken to represent the natural activity of the water in this area. The values determined ranged from 0.36 to 3.90×10^{-12} grams per liter, or 0.36 to 3.90×10^{-15} curies per milliliter (fig. 16). One sample from the Peconic River near Riverhead was reported to have 4.49×10^{-10} grams per liter, which is about ten times the maximum permissible activity (Natl. Bur. Standards, 1953, p. 14). This activity cannot be due to contamination from the Brookhaven National Laboratory, for the analytical method used responds only to radium (Curtis and Davis, 1943), which is used in negligible amounts at the Laboratory, and as subsequent samples from this point were entirely normal, this one high count was probably somehow in error. Unexplained high counts are occasionally obtained by all workers who are attempting to detect activity near the limit of resolution of their equipment.

The distribution of radium in the surface-water and ground-water samples was much the same, and no distinction could be seen between the high-nitrate or normal ground-water samples or between the streams with or without duck farms. The total number of samples was insufficient, however, to permit anything like a proper study. There does appear to be a scattering or spreading out of values at the high end, as can be seen in the histogram shown in figure 16. This could be taken as indicating that some additional factor, not present in the others, had contributed radium to the samples with more than 3×10^{-12} curies per liter, or it could be regarded as some inadequacy in the number or type of samples collected, or in their analysis. As the six high-radium samples have nothing else in common, the writer is inclined to the latter opinion.

ARTIFICIAL ACTIVITY IN GROUND WATER AND SURFACE WATER

About 200 water samples were collected from 18 wells and 10 surface-water sampling points in or near the Laboratory tract between November 1950 and March 1953. Analyses of some samples were made by the U.S. Bureau of Standards; others were made by the Brookhaven National Laboratory. The results of analyses are given in table 5. The identity and location of the sampling points are shown on plate 1.

ANALYTICAL PROCEDURES

The possible radioactive materials that might be found in the water may be divided into two groups. The first group, the alpha emitters, includes the naturally radioactive elements, uranium, thorium, and their daughter products, and also the pile-produced synthetic element, plutonium. These materials also give out beta and gamma radiation approximately equal in amount to the alpha activity. The second group includes those substances which produce beta and gamma radiation, but no alpha radiation, and includes the fission products from uranium and also a variety of synthetic elements produced by neutron bombardment in the pile. As the irradiated uranium slugs from the pile are not chemically separated at Brookhaven, the so-called mixed-fission-products do not necessarily form the bulk of the waste.

The National Bureau of Standards determined the radium content of the water samples submitted to them by the extraction of radon gas from the water samples. The methods used at Brookhaven involved different techniques, as their purpose was to search for solids in suspension or in solution in the water, rather than a gas. Three methods of concentrating the activity were employed, called here "ashed," "acid," and "plain." Each method has, in principal, its advantages and limitations, but in actual use their relative merits were difficult to distinguish. Comparison between them suggested that the results were commonly erratic. More work needs to be done on methods of measuring activity in water, not so much to increase the sensitivity, but to determine what methods of collecting and concentrating the samples will provide the most uniform, reliable, and informative data.

The ashed samples were prepared by filtering solids as small as 0.7 μ diameter from the water samples onto Whatman No. 41 filter paper, ashing the filter paper, and counting the residue. A little of the activity may be volatilized or carried off by the smoke in the ashing process, but such losses are not believed to be significant. More recent work by Max Weiss, of the Brookhaven Health Physics group, however, has shown that an appreciable but variable proportion of the particulate activity in the fallout, which the ashing procedure is in part intended to segregate, passes through the Whatman No. 41 paper but can be retained by a molecular hydrosol filter. Inadequate filtering, therefore, may partly explain the apparent erratic relation between the activity found in the ashed, plain, and acid samples.

The plain samples were concentrated by evaporation over a hot-plate until only a few milliliters, or perhaps even drops, remained of the original sample. The remaining liquid was then transferred to a small aluminum planchet where the evaporation was completed. It has been known for some time that, where only trace amounts of activity are present in the water, a large part or even all of the active ions will be adsorbed on the glass vessel used for the initial evaporation and therefore will not be found on the planchet when the count is made.

Acid treatment of the samples was intended to prevent this adsorption. In this procedure, a small quantity of nitric acid is added to the original sample, which reduces significantly the adsorption of activity onto the glass; but introduces other factors that are at least equally undesirable. After the residual liquid has been transferred to the planchet, the acid attacks the aluminum, making a bulky growth of aluminum salts. These salts mix with, and tend to cover and to shield, the activity deposited out of the water. Perhaps more important, the acid and the aluminum salts spatter and in this way mechanically remove what may be an appreciable fraction of the activity. Still further, some of the fission products, for example, iodine, are changed into volatile compounds by the acid and are lost.

More recently, since the last of the analyses reported in this paper were made, adsorption of radioactive ions by the glass has been largely prevented by boiling the plain water sample a small amount at a time in a jacketed vessel. The improvement appears to come from introducing the heat from all sides so that all the volume of the liquid boils, not just the bottom.

Sensitivity of any of the methods depends on several factors, the most obvious perhaps being the volume of the sample that is filtered or evaporated. The size of the sample that may be treated has a practical upper limit, however, for as the amount of filtrate or solid residue increases, it shields the radiation coming from the lower part. Nothing is gained by using more than the amount of liquid required to yield a thin film of residue on the planchet. In actual practice, the samples filtered were as large as 4.3 to 4.5 liters, whereas the samples evaporated ranged from 0.5 to 1 liter.

Sensitivity also depends on the counting time. Samples were counted for 30 minutes, and a statistical reliability figure of 90 percent was used for counting calculations. Under these conditions, the minimum detectable activity ranged from 1.8 to 2.1 counts per minute for beta activity and from 0.14 to 0.25 counts per minute for alpha activity, depending on the background. It would be difficult to lower these levels of minimum detectable activity. Increasing the counting time to 2 hours would only halve the above figures and would introduce the possibility of errors due to background variation.

The counting efficiency ranged from 24.2 to 24.5 percent for the scintillation counters used to detect alpha activity, to 10.4 to 15.7 percent for the Geiger-Müller counters used for beta-gamma counting. Actually, the GM tubes responded to very little but the beta radiation.

With these efficiencies, and the foregoing minimum detectable counts per minute, the minimum detectable activities, expressed in curies per milliliter are as follows:

Sample (liters)	*Range*
Beta-activity minima	
0.5	10.3×10^{-15}—18.3×10^{-15}
1	5.1×10^{-15}—9.1×10^{-15}
4.3–4.5	1.2×10^{-15}—2.1×10^{-15}
Alpha activity minima	
0.5	5.1×10^{-16}—9.3×10^{-16}
1	2.6×10^{-16}—4.6×10^{-16}
4.3–4.5	$.6\times10^{-16}$—1.1×10^{-16}

ANALYTICAL RESULTS

GROUND WATER

Data on radioactivity in ground water are given in table 5. None of the ground-water samples tested at Brookhaven showed any alpha activity. Fourteen samples showed beta activity, the maximum being 5×10^{-14} curies per milliliter, an amount that is negligible when compared to the 3-month average limit of 3×10^{-12} curies per milliliter that is allowed for the Brookhaven National Laboratory liquid waste effluent. Of these 14 ground-water samples, 10 showed activity in the ashed samples, 5 in the plain samples, and 8 in the acid samples. Only two samples showed activity according to all three methods of testing. The failure of the tests to give consistent results is indicative of the problems that must be expected when dealing with such low levels of activity.

The 14 samples were distributed apparently at random over the period of sampling and showed no relation to the dates of the test explosions of atom bombs (fig. 17). Max Weiss, of the Brookhaven National Laboratory Health Physics Department, believed that this beta activity represented the natural activity of the water and was not the result of glassware contamination or of erratic counter operation.

SURFACE WATER

Data on radioactivity of surface water are given in table 5.

Alpha activity was found in only four of the surface-water samples, the maximum being 8.3×10^{-16} curies per milliliter. It is believed to have been due to radon or thoron daughter products brought down by rain just before the time of collection, as the activity was found to be rather short lived.

Beta activity was found in 55 surface-water samples, the maximum being 3.7×10^{-13} curies per milliliter. This relatively large number of samples is partly due to the extra samples collected in October 1951 when fallout from atom bomb tests in Nevada first made its appearance in important quantities in this area. Although most of the activity was found in the samples collected within a few days after the arrival of the fallout, and only a few active samples were found as much as 2 or 3 months later, the data are insufficient to show how long detectable activity persisted in the surface water of this area following each of the tests.

Of the 55 samples of surface water in which beta activity was found, 38 showed activity in the ashed sample, 21 in the plain sample, and 43 in the acid samples. However, only 10 samples showed activity in all 3 tests, and there was no indication as to which test was the most sensitive (figs. 18, 19).

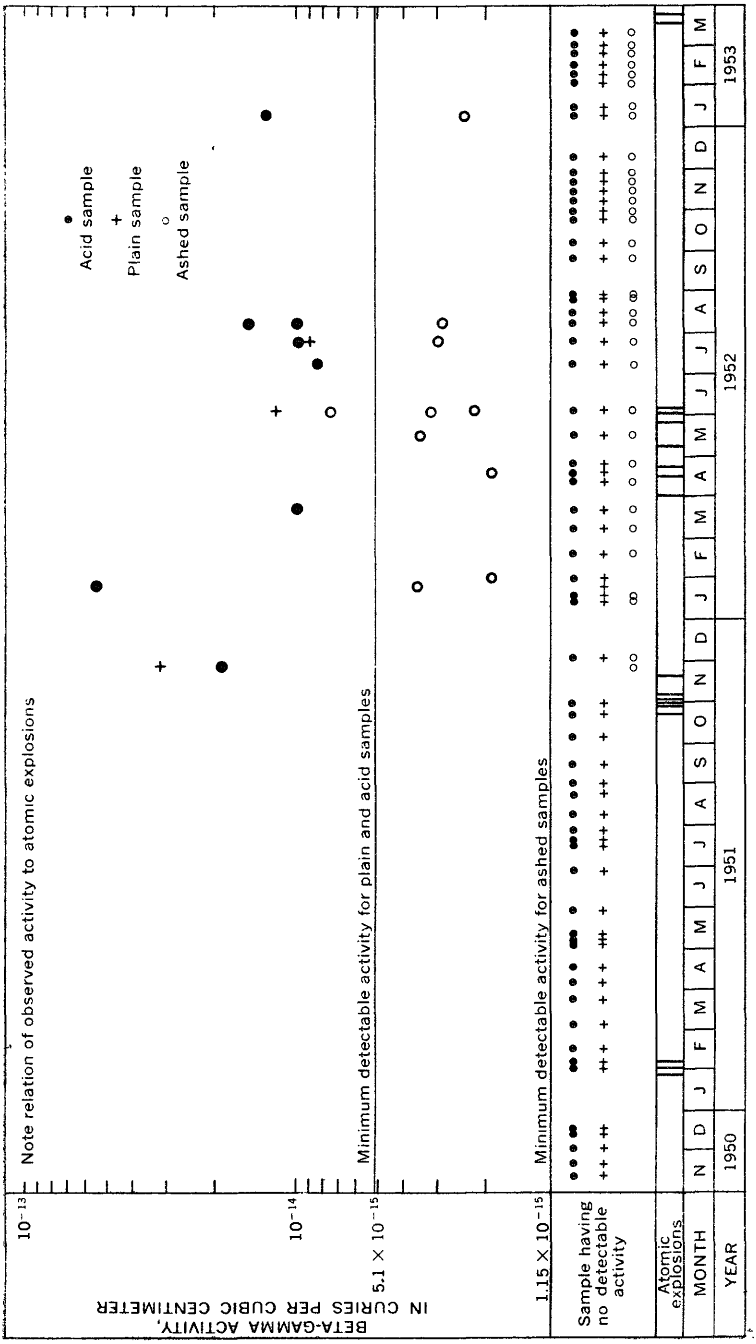

FIGURE 17.—Dates of collection and observed activity of ground-water samples: plain, acid, and ashed.

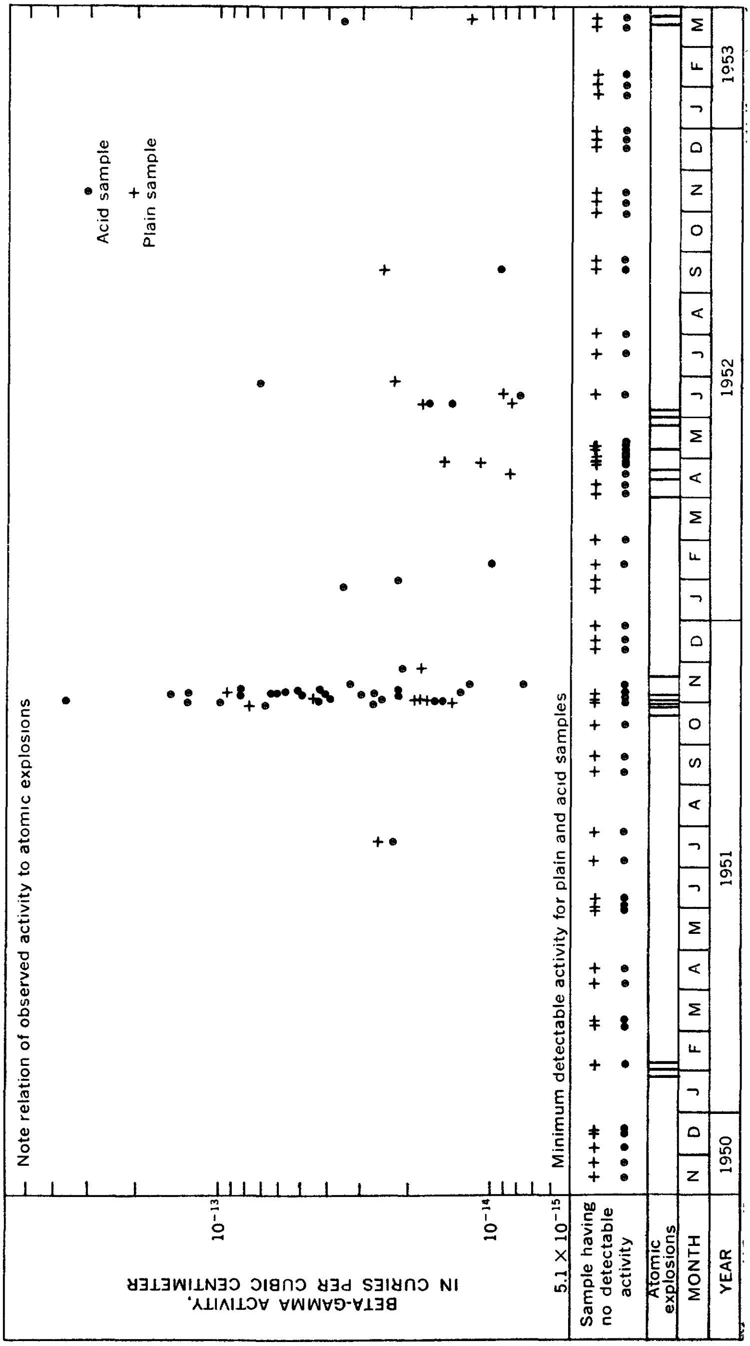

FIGURE 18.—Dates of collection and observed activity of surface-water samples, plain and acid.

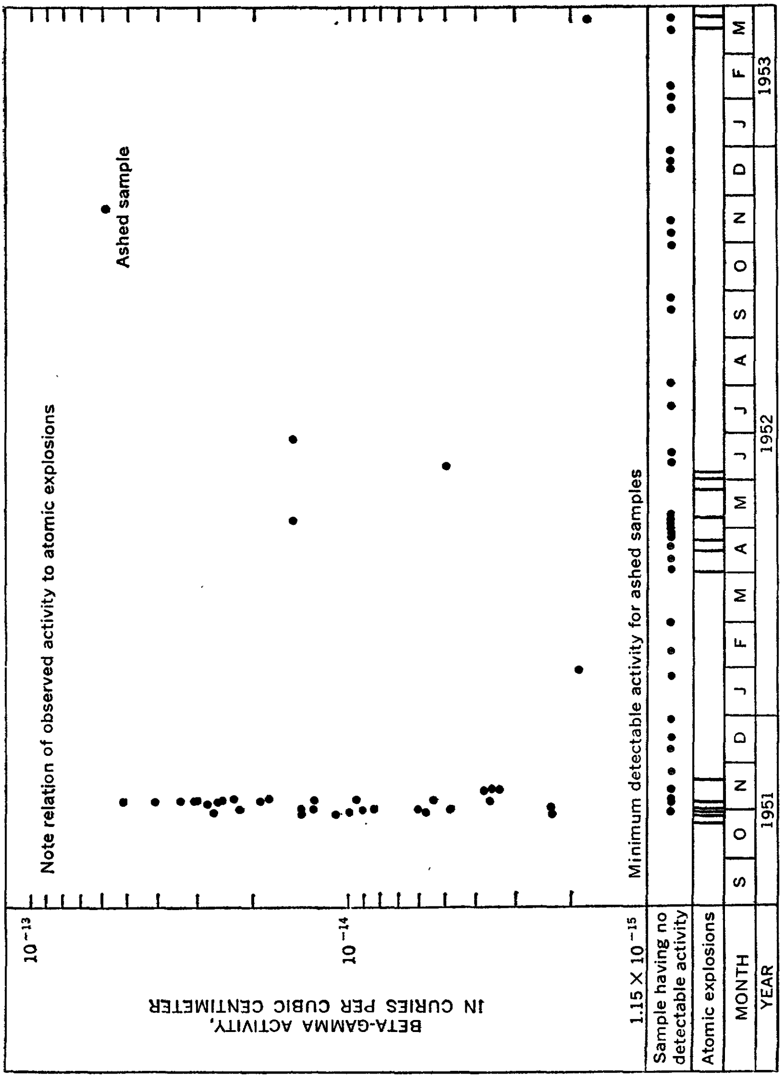

FIGURE 19.—Dates of collection and observed activity of surface-water samples, ashed.

TABLE 5.—*Radioactivity in ground-water and surface-water samples in and near Brookhaven National Laboratory*

[In curies per milliliter; B indicates no detectable activity above background]

Collection date	Sample		
	Ashed	Plain	Acid
GROUND WATER			
BETA-GAMMA ACTIVITY			
Well S3197 [Brookhaven Laboratory supply well 2: Diameter 12 in., 135 ft deep, 50 ft depth to water, 2,200 ft west of reactor]			
Jan. 9, 1953	2.4×10^{-15} $\pm1.7\times10^{-15}$	B	1.3×10^{-14} $\pm .7\times10^{-14}$
Well S6405 [Brookhaven Laboratory test well: Diameter 2½ in., 41 ft deep, 8 ft depth to water, 1.4 miles east of reactor]			
June 3, 1952	3.2×10^{-15} $\pm1.4\times10^{-15}$	1.2×10^{-14} $\pm.6\times10^{-14}$	B
Well S6406 [Brookhaven Laboratory test well: Diameter 2½ in., 50 ft deep, 7 ft depth to water, 1.5 miles east of reactor]			
June 3, 1952	2.2×10^{-15} $\pm1.6\times10^{-15}$	1.2×10^{-14} $\pm0.6\times10^{-14}$	B
Well S6407 [Brookhaven Laboratory test well: Diameter 2½ in., 34 ft deep, 3 ft depth to water, 1.3 miles northeast of reactor]			
Jan. 25, 1952	3.6×10^{-15} $\pm1.7\times10^{-15}$	B	5.5×10^{-14} $\pm1.5\times10^{-14}$
Jan. 31, 1952	1.9×10^{-15} $\pm1.5\times10^{-15}$	B	B
June 3, 1952	7.5×10^{-15} $\pm1.7\times10^{-15}$	B	B
Well S6426 [Brookhaven Laboratory test well: Diameter 4 in., 85 ft deep, 30 ft depth to water, 1.2 miles southeast of reactor]			
May 16, 1952	3.5×10^{-15} $\pm1.6\times10^{-15}$	B	B
Well S6697 [Brookhaven Laboratory supply well 3: Diameter 12 in., 100 ft deep, 34 ft depth to water, 2,000 ft east of reactor]			
July 8, 1952	B	B	8.3×10^{-15} $\pm6.8\times10^{-15}$

TABLE 5.—*Radioactivity in ground-water and surface-water samples in and near Brookhaven National Laboratory*—Continued

[In curies per milliliter; B indicates no detectable activity above background]

Collection date	Sample		
	Ashed	Plain	Acid

GROUND WATER—Continued

BETA-GAMMA ACTIVITY—Continued

Well S9141

[Mastic Acres Realty Company, Shirley: Diameter 2 in., 50 ft deep, 40 ft depth to water, 5 miles south of reactor]

Mar. 21, 1952	B	B	1.0×10^{-14} $\pm0.7\times10^{-14}$
July 25, 1952	3.0×10^{-15} $\pm1.5\times10^{-15}$	9.0×10^{-15} $\pm6.4\times10^{-15}$	9.8×10^{-15} $\pm6.4\times10^{-15}$

Well S9143

[Frank Becker, Weeks Avenue, Center Moriches: Diameter 1¼ in., 30 ft deep, 15 ft depth to water, 3.5 miles southeast of reactor]

Aug. 8, 1952	2.9×10^{-15} $\pm1.5\times10^{-15}$	1.0×10^{-14} $\pm0.7\times10^{-14}$	1.0×10^{-14} $\pm0.7\times10^{-14}$

Well S9144

[Brookhaven Town Police Substation, Center Moriches: Diameter 2 in., 40 ft deep, depth to water 20 ft, 6 miles southeast of reactor]

Nov. 26, 1951	B	3.2×10^{-14} $\pm1.3\times10^{-14}$	1.9×10^{-14} $\pm1.5\times10^{-14}$
Apr. 18, 1952	1.9×10^{-15} $\pm1.7\times10^{-15}$	B	B
Aug. 8, 1952	B	B	1.5×10^{-14} $\pm0.7\times10^{-14}$

SURFACE WATER

ALPHA ACTIVITY

Peconic River at Edwards Avenue, Calverton

[8 miles east of reactor]

June 11, 1952	5.0×10^{-16} $\pm3.2\times10^{-16}$	B	8.3×10^{-16} $\pm3.1\times10^{-16}$

Carmans River, at Route 27, South Haven

[5 miles south of reactor]

Nov. 7, 1952	1.4×10^{-16} $\pm0.9\times10^{-16}$	-------------------	B
May 2, 1952	B	B	5.0×10^{-16} $\pm3.3\times10^{-16}$

TABLE 5.—*Radioactivity in ground-water and surface-water samples in and near Brookhaven National Laboratory*—Continued

[In curies per milliliter; B indicates no detectable activity above background]

Collection date	Sample		
	Ashed	Plain	Acid
SURFACE WATER—Continued			
ALPHA ACTIVITY—Continued			
Artist Lake, Middle Island [3 miles northwest of reactor]			
Sept. 21, 1951	--------------------	3.6×10^{-16} $\pm1.8\times10^{-16}$	B
BETA-GAMMA ACTIVITY			
Peconic River at Schultz Road, Manorville [2.5 miles east of reactor]			
Oct. 31, 1951	2.7×10^{-14} $\pm0.2\times10^{-14}$	B	B
Nov. 2, 1951	1.4×10^{-14} $\pm0.2\times10^{-14}$	1.9×10^{-14} $\pm1.2\times10^{-14}$	B
Nov. 7, 1951	4.1×10^{-14} $\pm0.2\times10^{-14}$	--------------------	4.9×10^{-14} $\pm1.6\times10^{-14}$
Nov. 8, 1951	2.3×10^{-14} $\pm0.2\times10^{-14}$	--------------------	4.2×10^{-14} $\pm0.8\times10^{-14}$
Feb. 12, 1952	B	B	1.0×10^{-14} $\pm0.7\times10^{-14}$
June 11, 1952	B	8.5×10^{-15} $\pm6.2\times10^{-15}$	1.4×10^{-14} $\pm0.7\times10^{-14}$
Sept. 18, 1952	B	2.5×10^{-14} $\pm0.7\times10^{-14}$	B
Peconic River at Edwards Avenue, Calverton [8 miles east of reactor]			
Oct. 31, 1951	1.1×10^{-14} $\pm0.2\times10^{-14}$	B	B
Nov. 2, 1951	4.8×10^{-15} $\pm1.5\times10^{-15}$	1.8×10^{-14} $\pm1.2\times10^{-14}$	2.5×10^{-14} $\pm1.4\times10^{-14}$
Nov. 7, 1951	3.0×10^{-15} $\pm2.0\times10^{-15}$	--------------------	1.3×10^{-13} $\pm0.2\times10^{-13}$
Nov. 8, 1951	1.8×10^{-14} $\pm0.2\times10^{-14}$	--------------------	5.7×10^{-14} $\pm0.9\times10^{-14}$
Nov. 14, 1951	3.7×10^{-15} $\pm1.5\times10^{-15}$	--------------------	3.2×10^{-14} $\pm0.7\times10^{-14}$
June 11, 1952	5.0×10^{-15} $\pm1.8\times10^{-15}$	1.8×10^{-14} $\pm0.7\times10^{-14}$	1.7×10^{-14} $\pm0.7\times10^{-14}$
Sept. 18, 1952	B	B	9.4×10^{-15} $\pm6.8\times10^{-15}$

TABLE 5.—*Radioactivity in ground-water and surface-water samples in and near Brookhaven National Laboratory*—Continued

[In curies per milliliter; B indicates no detectable activity above background]

Collection date	Sample		
	Ashed	Plain	Acid

SURFACE WATER—Continued

BETA-GAMMA ACTIVITY—Continued

Peconic River at gaging station, Riverhead

[11 miles east of reactor]

Oct. 31, 1951	1.0×10^{-14} $\pm0.2\times10^{-14}$	1.4×10^{-14} $\pm1.3\times10^{-14}$	1.3×10^{-13} $\pm0.2\times10^{-13}$
Nov. 2, 1951	8.3×10^{-15} $\pm0.2\times10^{-15}$	1.7×10^{-14} $\pm1.2\times10^{-14}$	1.6×10^{-14} $\pm1.4\times10^{-14}$
Nov. 7, 1951	3.1×10^{-14} $\pm0.2\times10^{-14}$	------------------ ------------------	6.2×10^{-14} $\pm1.6\times10^{-14}$
Nov. 8, 1951	3.4×10^{-14} $\pm0.2\times10^{-14}$	------------------ ------------------	5.1×10^{-14} $\pm0.9\times10^{-14}$
Nov. 14, 1952	3.5×10^{-15} $\pm1.5\times10^{-15}$	------------------	1.2×10^{-14} $\pm0.7\times10^{-14}$
Jan. 25, 1952	B	B	3.5×10^{-14} $\pm1.4\times10^{-14}$
Jan. 31, 1952	1.9×10^{-15} $\pm1.6\times10^{-15}$	B	2.2×10^{-14} $\pm1.4\times10^{-14}$

Terrell Pond, at outlet, Route 27, East Moriches

[8 miles southeast of reactor]

Nov. 26, 1951	B	1.8×10^{-14} $\pm1.3\times10^{-14}$	2.1×10^{-14} $\pm1.5\times10^{-14}$
Apr. 18, 1951		8.6×10^{-15} $\pm6.8\times10^{-15}$	B

Forge River, West Branch, at Route 27, Moriches

[4.5 miles south of reactor]

Oct. 31, 1951	1.4×10^{-14} $\pm0.2\times10^{-14}$	B	B
Nov. 2, 1951	1.3×10^{-14} $\pm0.2\times10^{-14}$	4.3×10^{-14} $\pm1.3\times10^{-14}$	4.3×10^{-14} $\pm1.5\times10^{-14}$
Nov. 7, 1951	5.2×10^{-14} $\pm0.2\times10^{-14}$	------------------	3.0×10^{-14} $\pm0.9\times10^{-14}$
Nov. 8, 1951	9.4×10^{-15} $\pm1.6\times10^{-15}$	------------------	B
Nov. 14, 1951	B	------------------	1.2×10^{-14} $\pm0.7\times10^{-14}$

TABLE 5.—*Radioactivity in ground-water and surface-water samples in and near Brookhaven National Laboratory*—Continued

[In curies per milliliter; B indicates no detectable activity above background]

Collection date	Sample		
	Ashed	Plain	Acid
SURFACE WATER—Continued **BETA-GAMMA ACTIVITY—Continued** **Forge River, East Branch, at Route 27** [4.5 miles south of reactor]			
Oct. 31, 1951	5.7×10^{-15} $\pm1.8\times10^{-15}$	B	2.7×10^{-14} $\pm1.5\times10^{-14}$
Nov. 2, 1951	2.2×10^{-14} $\pm0.2\times10^{-14}$	2.5×10^{-14} $\pm1.3\times10^{-14}$	3.7×10^{-13} $\pm0.2\times10^{-13}$
Nov. 7, 1951	3.0×10^{-14} $\pm0.2\times10^{-14}$	------------------	6.4×10^{-14} $\pm0.8\times10^{-14}$
Nov. 8, 1951	3.6×10^{-15} $\pm1.5\times10^{-15}$	------------------	8.4×10^{-14} $\pm0.9\times10^{-14}$
Nov. 14, 1951	B	------------------	1.2×10^{-14} $\pm0.7\times10^{-14}$
Forge River, combined flow of both branches, at Route 27, Moriches [4.5 miles south of reactor]			
July 20, 1951	------------------	2.6×10^{-14} $\pm0.8\times10^{-14}$	2.3×10^{-14} $\pm0.8\times10^{-14}$
Oct. 29, 1951	------------------	7.8×10^{-14} $\pm0.8\times10^{-14}$	6.8×10^{-14} $\pm0.8\times10^{-14}$
Carmans River, at gaging station, Yapbank [3 miles southwest of reactor]			
Nov. 2, 1951	6.0×10^{-15} $\pm1.5\times10^{-15}$	1.8×10^{-14} $\pm1.2\times10^{-14}$	1.5×10^{-14} $\pm1.4\times10^{-14}$
Nov. 7, 1951	B	------------------	2.7×10^{-14} $\pm0.9\times10^{-14}$
Nov. 14, 1951	3.4×10^{-15} $\pm1.7\times10^{-15}$	------------------	7.6×10^{-15} $\pm6.3\times10^{-15}$
Carmans River, at Route 27, South Haven [5 miles south of reactor]			
Nov. 2, 1951	9.0×10^{-15} $\pm0.2\times10^{-15}$	B	B
Nov. 7, 1951	2.5×10^{-14} $\pm0.2\times10^{-14}$	------------------	4.1×10^{-14} $\pm0.9\times10^{-14}$
Nov. 8, 1951	5.4×10^{-15} $\pm1.7\times10^{-15}$	------------------	2.2×10^{-14} $\pm0.7\times10^{-14}$
Apr. 27, 1952	B	1.5×10^{-14} $\pm0.7\times10^{-14}$	B
Apr. 28, 1952	B	1.1×10^{-14} $\pm0.7\times10^{-14}$	B
May 5, 1952	1.5×10^{-14} $\pm0.2\times10^{-14}$	B	B

TABLE 5.—*Radioactivity in ground-water and surface-water samples in and near Brookhaven National Laboratory*—Continued

[In curies per milliliter; B indicates no detectable activity above background]

Collection date	Sample		
	Ashed	Plain	Acid
SURFACE WATER—Continued			
BETA-GAMMA ACTIVITY—Continued			
Tuthills Creek, at Route 27, Patchogue [10 miles southwest of reactor]			
Oct. 31, 1951	2.3×10^{-15} $\pm1.5\times10^{-15}$	B	1.0×10^{-13} $\pm0.2\times10^{-13}$
Nov. 2, 1951	2.3×10^{-15} $\pm1.5\times10^{-15}$	4.5×10^{-14} $\pm1.5\times10^{-14}$	B
Nov. 8, 1951	B	------------------	1.3×10^{-14} $\pm0.7\times10^{-14}$
Long Pond (Lake Panamoka), Wading River [4 miles northeast of reactor]			
Nov. 7, 1951	1.3×10^{-14} $\pm0.2\times10^{-14}$	------------------	8.4×10^{-14} $\pm1.6\times10^{-14}$
Artist Lake, Middle Island [3 miles northwest of reactor]			
Nov. 6, 1951	2.8×10^{-14} $\pm0.2\times10^{-14}$	9.4×10^{-14} $\pm1.5\times10^{-14}$	1.5×10^{-13} $\pm0.2\times10^{-13}$
Dec. 10, 1951	B	------------------	2.8×10^{-14} $\pm0.8\times10^{-14}$
June 27, 1952	1.5×10^{-15} $\pm1.2\times10^{-15}$	2.3×10^{-14} $\pm1.3\times10^{-14}$	7.2×10^{-14} $\pm1.5\times10^{-14}$
Mar. 23, 1953	1.8×10^{-15} $\pm1.4\times10^{-15}$	1.2×10^{-14} $\pm0.7\times10^{-14}$	3.6×10^{-14} $\pm0.8\times10^{-14}$
Lake Ronkonkoma [13 miles west of reactor]			
Nov. 6, 1951	2.6×10^{-14} $\pm0.2\times10^{-14}$	------------------	4.0×10^{-14} $\pm1.5\times10^{-14}$
Deep Pond (Lake Wauwepex) Wading River [5 miles northeast of reactor]			
Nov. 7, 1951	1.9×10^{-14} $\pm0.2\times10^{-14}$	------------------	2.2×10^{-14} $\pm1.5\times10^{-14}$
June 17, 1952	B	9.1×10^{-15} $\pm6.8\times10^{-15}$	7.9×10^{-15} $\pm6.5\times10^{-15}$

TABLE 6.—*Chemical analyses of ground and surface water in and near Brookhaven National Laboratory, Suffolk County, N.Y.*

Concentrations are in parts per million (ppm) except pH, specific conductance (in micromhos at 25°C), radium (in curies per liter x 10^{-12}), and color. Tr., trace, indicates less than 0.5 ppm. Of the chemical constituents determined at Brookhaven National Laboratory, accuracy of the chlorides is about 1 or 2 ppm and of the nitrates is about 5 ppm. Where two figures for pH are given, the first is that of the fresh sample right after collection; the second is that after exposure for 1 week or more.

[Wells arranged in approximate order of increasing nitrate content]

Date collected	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Specific conductance ($K \times 10^6$)	Color	pH		Phosphate (PO_4)	Copper (Cu)	Zinc (Zn)	Aluminum (Al)	Radium (Ra)
															1st	2d					
NORMAL GROUND WATER FROM WELLS SCREENED IN UPPER PLEISTOCENE DEPOSITS																					
Well S6432																					
[In Laboratory tract in a waste storage area. Test well: Diameter 4 in., depth 120 ft, depth to water 41 ft. About 800 ft north of reactor]																					
Dec. 17, 1948	9.6	0.75	2.1	1.1	3.8	0.4	11	2.6	4.4	0.0	0.1	29	36.4	2	6.7	------	0	0	0	0	0.66
Well S9141																					
[Mastic Acres Realty Co. sales office, Shirley. Domestic supply well, diameter 2 in., depth 50 ft, depth to water 40 ft. About 5 miles south of reactor. Zinc and copper possibly from plumbing]																					
Feb. 13, 1950	6.1	0.41	1.3	1.3	5.4	1.1	10	6.6	5.9	0.0	0.1	32	51.4	2	6.9	------	0	0.1	5	0.2	1.23
Feb. 5, 1951	------	------	------	------	------	------	------	------	6	------	0	------	59.9	------	------	------	------	------	------	------	------
Apr. 5, 1951	------	------	------	------	------	------	------	------	6	------	0	------	66.1	------	------	------	------	------	------	------	------
July 16, 1951	------	------	------	------	------	------	------	------	6	------	0	------	51.4	------	6.0	------	------	------	------	------	------
Oct. 22, 1951	------	------	------	------	------	------	------	------	6	------	0	------	58.9	------	6.3	------	------	------	------	------	------
Mar. 21, 1952	------	------	------	------	------	------	------	------	8	------	10	------	81.4	------	6.5	7.4	------	------	------	------	------
July 25, 1952	------	------	------	------	------	------	------	------	8	------	10	------	78.2	------	5.7	7.2	------	------	------	------	------
Oct. 30, 1952	------	------	------	------	------	------	------	------	5	------	Tr.	------	52.9	------	5.9	7.2	------	------	------	------	------
Jan. 15, 1953	------	------	------	------	------	------	------	------	4	------	5	------	64.6	------	6.0	7.2	------	------	------	------	------
Well S6405																					
[In Laboratory tract. Test well: Diameter 2½ in., depth 41 ft, depth to water 8 ft. About 1.4 miles east of reactor]																					
Oct. 18, 1948	7.1	0.11	2.2	1.3	4.8	0.6	2	13	5.9	0.0	0.2	40	57.8	2	5.5	------	0	0	0	0.2	0.94
Dec. 17, 1948	5.9	.19	2.1	1.6	4.7	.9	1	12	6.0	.1	.1	36	59.4	2	5.5	------	0	0	0	0	------
June 7, 1949	------	.17	------	------	------	------	3	------	7.2	.0	.2	------	57.7	3	5.1	------	0	0	0	------	2.22
July 29, 1949	------	.47	------	------	------	------	4	8.0	7.1	.0	.2	------	56.8	4	5.1	------	.3	------	------	------	1.36
Feb. 2, 1951	------	------	------	------	------	------	------	------	7	------	0	------	54.8	------	------	------	------	------	------	------	------
May 11, 1951	------	------	------	------	------	------	------	------	6	------	0	------	49.1	------	5.5	------	------	------	------	------	------
Aug. 31, 1951	------	------	------	------	------	------	------	------	7	------	0	------	52.4	------	5.2	------	------	------	------	------	------
Jan. 11, 1952	------	------	------	------	------	------	------	------	7	------	0	------	52.5	------	5.1	------	------	------	------	------	------

June 3, 1952	------	------	------	------	------	------	------	------	7	------	0	------	58.2	------	5.2	5.5	------	------	------	------	------
Aug. 15, 1952	------	------	------	------	------	------	------	------	10	------	0	------	74.0	------	4.8	5.0	------	------	------	------	------
Nov. 28, 1952	------	------	------	------	------	------	------	------	10	------	0	------	69.6	------	5.1	5.1	------	------	------	------	------
Mar. 3, 1953	------	------	------	------	------	------	------	------	10	------	0	------	74.5	------	5.0	5.0	------	------	------	------	------

Well S9142

[Frank Stiefel's Esso Service Station. Mastic, Domestic supply well: Diameter 2 in., depth 60 ft, depth to water 30 ft. About 5 miles southeast of reactor]

Feb. 13, 1950	6.0	0.23	1.4	2.0	5.5	1.4	8	8.0	6.9	0.0	0.2	34	52.3	4	6.5	------	0	0	1.2	0.1	0.58
Feb. 5, 1951	------	------	------	------	------	------	------	------	8	------	0	------	56.4	------	------	------	------	------	------	------	------
Apr. 16, 1951	------	------	------	------	------	------	------	------	7	------	0	------	50.6	------	5.7	------	------	------	------	------	------
July 20, 1951	------	------	------	------	------	------	------	------	7	------	0	------	52.9	------	6.5	------	------	------	------	------	------
Oct. 29, 1951	------	------	------	------	------	------	------	------	6	------	0	------	52.0	------	6.0	------	------	------	------	------	------
Apr. 11, 1952	------	------	------	------	------	------	------	------	5	------	0	------	47.8	------	5.8	7.0	------	------	------	------	------
July 25, 1952	------	------	------	------	------	------	------	------	------	------	0	------	56.5	------	5.8	7.0	------	------	------	------	------
Nov. 7, 1952	------	------	------	------	------	------	------	------	7	------	Tr.	------	57.4	------	6.2	6.8	------	------	------	------	------
Feb. 2, 1953	------	------	------	------	------	------	------	------	6	------	Tr.	------	54.1	------	5.9	6.8	------	------	------	------	------

Well S6407

[In Laboratory tract. Test well: Diameter 2½ in., depth 34 ft, depth to water 3 ft. About 1.3 miles northeast of reactor]

Dec. 17, 1948	7.0	4.2	1.5	0.9	5.7	0.8	10	3.1	7.0	0.0	0.2	36	44.5	40	6.1	------	0	0	0	0.2	------
Nov. 15, 1949	11	2.2	1.0	.9	6.3	1.0	12	2.6	6.8	.0	.2	36	45.1	28	5.5	------	0	0	0	.3	1.14
Feb. 2, 1951	------	------	------	------	------	------	------	------	6	------	0	------	40.3	------	------	------	------	------	------	------	------
May 28, 1951	------	------	------	------	------	------	------	------	5	------	0	------	41.2	------	6.2	------	------	------	------	------	------
Sept. 14, 1951	------	------	------	------	------	------	------	------	4	------	0	------	37.1	------	6.0	------	------	------	------	------	------
Jan. 25, 1952	------	------	------	------	------	------	------	------	4	------	0	------	34.0	------	6.3	------	------	------	------	------	------
June 3, 1952	------	------	------	------	------	------	------	------	5	------	0	------	47.3	------	5.8	7.2	------	------	------	------	------
Aug. 26, 1952	------	------	------	------	------	------	------	------	6	------	0	------	57.1	------	6.0	7.0	------	------	------	------	------
Dec. 10, 1952	------	------	------	------	------	------	------	------	5	------	0	------	45.2	------	6.1	7.0	------	------	------	------	------
Mar. 10, 1953	------	------	------	------	------	------	------	------	5	------	0	------	49.0	------	5.8	7.0	------	------	------	------	------

Well S5518

[In Laboratory tract. Supply well 7: Diameter 6 in., depth 54 ft, depth to water 32 ft, nominal capacity 30 gpm. About 2.5 miles north of reactor]

May 13, 1948	6.9	0.20	1.3	1.2	3.3	0.5	5	5.9	4.9	0.0	0.4	28	38.9	------	5.8	------	0	0	------	0	------
Oct. 15, 1948	6.0	.01	1.5	1.3	3.2	.6	4	6.0	5.0	.0	.1	26	39.3	1	6.5	------	0	0	0	.2	------
Aug. 3, 1949	------	.50	------	------	------	------	8	5.0	4.5	.0	.2	------	38.3	2	5.8	------	------	------	------	------	3.61

Unnumbered State well

[LeKay, Ridge Rd., Ridge. Domestic well: Diameter 2 in., depth 67 ft, depth to water 50 ft. Hand pump. About 2.5 miles northwest of reactor]

Nov. 21, 1952	9.0	0.00	2.2	0.6	3.3	0.4	10.0	8.8	4.0	0.1	0.5	35	36.5	2	6.4	------	0.0	0.00	1.3	1.1	------

NOTE.—Manganese (Mn) 0.04; carbon dioxide (CO_2) 6.3, calculated.

TABLE 6.—*Chemical analyses of ground and surface water in and near Brookhaven National Laboratory, Suffolk County, N.Y.*—Con.

NORMAL GROUND WATER FROM WELLS SCREENED IN UPPER PLEISTOCENE DEPOSITS—Continued

Well S3197

[In Laboratory tract. Supply well 2: Diameter 12 in., depth 135 ft, depth to water 50 ft, nominal capacity 500 gpm. About 2,200 ft west of reactor]

Date collected	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Specific conductance ($K \times 10^5$)	Color	pH 1st	pH 2d	Phosphate (PO_4)	Copper (Cu)	Zinc (Zn)	Aluminum (Al)	Radium (Ra)
Apr. 16, 1948	9.1	.37	1.6	1.2	3.9	0.5	8	4.0	4.0	0.0	0.2	28	38.1	3	6.3		0	0	0		
June 17, 1948	9.5	.28	1.8	1.1	4.2	.7	8	4.4	4.8	.2	.2	29	37.0	1	6.9		0	0	0	0	
Oct. 15, 1948	9.2	.35	1.6	1.1	3.6	.5	8	4.2	4.8	.0	.2	28	38.7	3	6.5		0	0	0	.1	0.70
Dec. 21, 1948	7.6	.49	2.0	1.5	4.2	.7	10	4.9	5.4	.0	.5	30	43.5	6	6.5		0	0	0	0	
July 1, 1949	8.6	.04	2.4	1.4	4.3		9	4.4	6.0	.1	.5	32	45.6	1	5.7			0	0	.9	3.13
Dec. 15, 1950									7		Tr.		45.1								
Mar. 23, 1951									6		0		43.0								
June 27, 1951									6		0		44.8		6.1						
Oct. 5, 1951									6		0		44.1		6.1						
Mar. 7, 1952									5		0		40.6		6.3	7.4					
July 8, 1952									6		0		46.3		6.0	7.4					
Oct. 6, 1952									6		0		46.3		6.1	7.2					
Jan. 9, 1953									4		0		38.3		6.3	7.1					

Well S5234

[In Laboratory tract. Formerly supply well 4, abandoned 1949: Diameter 6 in., depth 110 ft, depth of water 73 ft, nominal capacity 175 gpm. Was about 4,000 ft southwest of reactor]

Date collected	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Specific conductance ($K \times 10^5$)	Color	pH 1st	pH 2d	Phosphate (PO_4)	Copper (Cu)	Zinc (Zn)	Aluminum (Al)	Radium (Ra)
May 27, 1948	9.1	7.5	2.5	1.7	4.2	0.6	9	8.5	4.4	0.1	0.8	35	49.9	10	5.9		0.1	0	0	0	
Oct. 15, 1948	8.5	.31	2.7	1.7	3.7	.5	10	7.9	4.2	.0	.8	34	49.7	7	6.4		0	0	0	.1	
Dec. 21, 1948	7.0	1.5	2.8	2.0	4.1	.8	10	8.9	4.8	.0	.6	35	51.6	10	6.3		0	0	0	.1	1.68

Well S6426

[In Laboratory tract. Test well: Diameter 4 in., depth 85 ft, depth to water 30 ft. About 1.2 miles southeast of reactor]

Date collected	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Specific conductance ($K \times 10^5$)	Color	pH 1st	pH 2d	Phosphate (PO_4)	Copper (Cu)	Zinc (Zn)	Aluminum (Al)	Radium (Ra)
Nov. 13, 1950									7		0		67.1								
May 7, 1951									7		0		63.1		6.7						
Aug. 24, 1951									6		0		56.5		6.6						
Jan. 18, 1952									6		0		58.5		6.4						
May 16, 1952									6		0		59.4		6.7	7.5					
Aug. 29, 1952									6		0		51.4		6.2	7.2					
Nov. 28, 1952									5		0		50.2		7.0	7.2					
Feb. 24, 1953									6		0		51.7		6.5	7.1					

Well S6697

[In Laboratory tract. Supply well 3B: Diameter 12 in., depth 100 ft, depth to water 34 ft, nominal capacity 750 gpm. About 2,000 ft east of reactor]

Nov. 22, 1950	--	--	--	--	--	--	--	--	6	--	0	--	63.0	--	--	--	--	--	--	--	--
Mar. 23, 1951	--	--	--	--	--	--	--	--	6	--	0	--	55.1	--	--	--	--	--	--	--	--
June 27, 1951	--	--	--	--	--	--	--	--	5	--	0	--	54.1	--	6.1	--	--	--	--	--	--
Oct. 5, 1951	--	--	--	--	--	--	--	--	5	--	Tr.	--	64.3	--	6.0	--	--	--	--	--	--
Mar. 7, 1952	--	--	--	--	--	--	--	--	6	--	Tr.	--	63.7	--	6.2	7.4	--	--	--	--	--
July 8, 1952	--	--	--	--	--	--	--	--	6	--	0	--	72.8	--	5.9	7.4	--	--	--	--	--
Oct. 6, 1952	--	--	--	--	--	--	--	--	7	--	Tr.	--	80.0	--	5.9	7.4	--	--	--	--	--
Jan. 9, 1953	--	--	--	--	--	--	--	--	6	--	Tr.	--	73.3	--	6.0	7.3	--	--	--	--	--

Well S6406

[In Laboratory tract. Test well: Diameter 2½ in., depth 50 ft, depth to water 7 ft. About 1.5 miles east of reactor]

Oct. 14, 1949	6.2	0.32	1.5	1.1	4.8	0.6	10	6.5	4.1	0.0	0.8	29	40.8	5	5.9	--	0	0	0	0.5	1.30
Feb. 2, 1951	--	--	--	--	--	--	--	--	8	--	0	--	47.4	--	--	--	--	--	--	--	--
May 11, 1951	--	--	--	--	--	--	--	--	7	--	0	--	46.5	--	5.9	--	--	--	--	--	--
Aug. 31, 1951	--	--	--	--	--	--	--	--	7	--	0	--	50.4	--	6.1	--	--	--	--	--	--
Jan. 11, 1952	--	--	--	--	--	--	--	--	6	--	0	--	44.4	--	6.1	--	--	--	--	--	--
June 3, 1952	--	--	--	--	--	--	--	--	6	--	0	--	46.6	--	6.2	7.2	--	--	--	--	--
Aug. 15, 1952	--	--	--	--	--	--	--	--	6	--	0	--	53.6	--	6.4	7.2	--	--	--	--	--
Dec. 10, 1952	--	--	--	--	--	--	--	--	5	--	0	--	42.2	--	6.2	6.9	--	--	--	--	--
Mar. 2, 1953	--	--	--	--	--	--	--	--	5	--	0	--	43.6	--	5.9	6.8	--	--	--	--	--

Well S2485

[At southeast corner Laboratory tract. Formerly Long Island Rail Road supply well: Diameter 8 in., depth 75 ft, depth to water 32 ft, nominal capacity estimated at 100 gpm. About 1.7 miles southeast of reactor]

May 27, 1948	9.7	0.33	1.8	1.4	6.3	0.6	9	10	4.8	0.0	2.3	41	56.1	3	6.8	--	0.1	0	0	0	--
Oct. 15, 1948	9.2	.01	2.3	1.6	5.9	.6	9	11	4.8	.0	1.2	40	57.8	1	6.3	--	0	0	0	.1	--
Dec. 21, 1948	8.4	1.6	2.4	1.6	5.6	.8	6	11	4.6	.1	1.7	40	56.9	3	6.6	--	0	0	0	0	--
July 1, 1949	9.4	.02	2.3	1.7	6.0		8	11	4.5	.0	1.8	42	57.3	1	5.9	--	--	0	0	1.7	1.93
Dec. 5, 1950	--	--	--	--	--	--	--	--	6	--	0	--	59.2	--	--	--	--	--	--	--	--
Mar. 23, 1951	--	--	--	--	--	--	--	--	4	--	0	--	59.5	--	--	--	--	--	--	--	--
June 27, 1951	--	--	--	--	--	--	--	--	5	--	0	--	58.5	--	6.1	--	--	--	--	--	--
Oct. 5, 1951	--	--	--	--	--	--	--	--	4	--	0	--	59.2	--	6.2	--	--	--	--	--	--
Mar. 7, 1952	--	--	--	--	--	--	--	--	4	--	0	--	59.3	--	6.3	7.2	--	--	--	--	--

TABLE 6.—*Chemical analyses of ground and surface water in and near Brookhaven National Laboratory, Suffolk County, N.Y.*—Con.

Date collected	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Specific conductance ($K \times 10^6$)	Color	pH		Phosphate (PO_4)	Copper (Cu)	Zinc (Zn)	Aluminum (Al)	Radium (Ra)
															1st	2d					
NORMAL GROUND WATER FROM WELLS SCREENED IN UPPER PLEISTOCENE DEPOSITS—Continued																					
Well S6425																					
[In Laboratory tract. Test well: Diameter 4 in., depth 85 ft, depth to water 30 ft. About 4,200 ft south of reactor]																					
Nov. 15, 1949	9.7	3.3	5.7	3.6	6.0	0.8	18	19	4.8	0.0	2.4	59	92.6	5	5.9		0	0	0	0.4	1.37
Feb. 2, 1951									5		0		82.0								
May 4, 1951									5		0		127		6.9						
Aug. 24, 1951									5		0		129		6.6						
Jan. 18, 1952									5		0		88.3		6.9						
May 16, 1952									5		Tr.		110		7.0	7.6					
Sept. 25, 1952									4		Tr.		84.5		7.0	7.4					
Well S2476																					
[In Laboratory tract. Supply well 1: Diameter 12 in., depth 101 ft, depth to water 35 ft, nominal capacity 500 gpm. About 1,600 ft southeast of reactor]																					
May 10, 1948	8.7	0.04	4.1	2.3	5.2	0.7	5	8.6	12(?)	0.0	2.5	48	78.6		5.8		0	0	0	0.2	
Dec. 21, 1948	7.3	1.8	2.4	1.5	4.0	.8	6	7.9	5.1	.1	.4	32	50.2	1	6.3		0	0	0	0	0.4
July 1, 1949	8.5	.23	4.7	2.6	4.7	2.0	8	11	8.9	.2	2.8	48	76.7	1	5.5		0	0	0	.7	1.53
Dec. 18, 1950									7		0		76.5								
Mar. 23, 1951									8		Tr.		78.9								
June 27, 1951									8		Tr.		79.2		6.0						
Oct. 5, 1951									8		Tr.		79.5		6.0						
Mar. 7, 1952									7		Tr.		69.4		6.2	7.4					
July 8, 1952									7		Tr.		85.4		5.9	7.4					
Oct. 6, 1952									7		Tr.		118		6.7	7.8					
Jan. 9, 1953									7		Tr.		94.0		6.3	7.4					
Well S6471																					
[In Laboratory tract. Test well: Diameter 1¼ in., depth 14 ft, depth to water 8 ft. Well destroyed in 1950. About 1.8 miles southeast of reactor]																					
July 29, 1949	6.4	.32	6.0	1.8	2.6	1.7	6	17	3.8	0.0	2.6	47	71.0	1	5.5		0	0	0	1.3	3.90

Well S9143

[Frank Becker. Weeks Ave., 0.1 mile north of five corners at Barnes Road, Center Moriches. Domestic well: Diameter 1¼ in., depth 30 ft, depth to water 15 ft. About 3.5 miles southeast of reactor]

Mar. 3, 1950	4.0	0.33	5.2	2.9	3.9	1.4	20	9.4	5.2	0.0	3.5	42	59.8	3	6.2	----	0	0	4	0.1	0.38
Feb. 16, 1951	----	----	----	----	----	----	----	----	4	----	0	----	28.9	----	----	----	----	----	----	----	----
Apr. 16, 1951	----	----	----	----	----	----	----	----	3	----	0	----	28.0	----	5.9	----	----	----	----	----	----
Aug. 8, 1951	----	----	----	----	----	----	----	----	4	----	Tr.	----	30.6	----	5.9	----	----	----	----	----	----
Dec. 3, 1951	----	----	----	----	----	----	----	----	4	----	Tr.	----	32.3	----	5.8	----	----	----	----	----	----
Apr. 25, 1952	----	----	----	----	----	----	----	----	4	----	0	----	29.9	----	5.8	7.4	----	----	----	----	----
Aug. 8, 1952	----	----	----	----	----	----	----	----	5	----	Tr.	----	41.6	----	5.8	7.0	----	----	----	----	----
Nov. 21, 1952	----	----	----	----	----	----	----	----	4	----	Tr.	----	40.1	----	6.0	7.1	----	----	----	----	----
Feb. 9, 1953	----	----	----	----	----	----	----	----	3	----	Tr.	----	38.6	----	5.8	7.2	----	----	----	----	----

Well S3405

[In Laboratory tract at sewage disposal plant. Supply well: Diameter 4 in., depth 65 ft, depth to water 22 ft, nominal capacity 65 gpm. About 1 mile northeast of reactor. Water classed as normal ground water on basis of complete chemical analyses. Some contamination from disposal plant itself may be possible]

May 13, 1948	6.8	0.17	7.2	1.7	3.9	1.6	11	14	5.6	0.0	7.3	56	83.1	----	6.2	----	0	0	0	0.1	----
Oct. 15, 1948	6.4	.45	4.5	1.2	3.7	1.7	9	8.8	5.1	.0	2.7	38	57.9	1	6.7	----	0	0	0	.1	----
July 1, 1949	7.1	.02	4.7	1.7	29		6	7.2	5.2	.1	6.2	44	63.4	2	5.7	----	----	0	0	1.3	1.63
Feb. 16, 1951	----	----	----	----	----	----	----	----	6	----	10	----	79.9	----	----	----	----	----	----	----	----
Apr. 5, 1951	----	----	----	----	----	----	----	----	6	----	10	----	82.3	----	----	----	----	----	----	----	----
July 16, 1951	----	----	----	----	----	----	----	----	6	----	15	----	91.2	----	5.9	----	----	----	----	----	----
Oct. 22, 1951	----	----	----	----	----	----	----	----	5	----	15	----	89.1	----	6.0	----	----	----	----	----	----
Mar. 21, 1952	----	----	----	----	----	----	----	----	6	----	15	----	101	----	6.6	7.4	----	----	----	----	----
July 8, 1952	----	----	----	----	----	----	----	----	5	----	10	----	95.0	----	5.8	7.4	----	----	----	----	----
Oct. 24, 1952	----	----	----	----	----	----	----	----	5	----	10	----	79.2	----	6.2	7.2	----	----	----	----	----
Jan. 15, 1953	----	----	----	----	----	----	----	----	5	----	5	----	80.8	----	5.9	7.0	----	----	----	----	----

Well S5362

[New York State Game Farm. Route 25, Middle Island. Domestic well: Diameter 2 in., depth 65 ft, depth to water 20 ft. About 2 miles northwest of reactor. Water may be slightly contaminated by fertilizer]

May 27, 1948	6.5	0.34	7.6	1.7	4.2	5.8	20	13	5.1	0.0	6.4	59	96.4	3	6.0	----	0	0	0	0.1	----
July 29, 1949	----	.13	----	----	----	----	18	10	6.8	.0	6.4	----	107	2	6.3	----	----	----	----	----	1.81

TABLE 6.—*Chemical analyses of ground and surface water in and near Brookhaven National Laboratory, Suffolk County, N.Y.*—Con.

HIGH NITRATE GROUND WATER FROM UPPER PLEISTOCENE DEPOSITS

Special sample 1

[Effluent from representative small cesspool. W. de Laguna, Wading River. Located adjacent to well S742]

Date collected	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Specific conductance ($K \times 10^6$)	Color	pH 1st	pH 2d	Phosphate (PO_4)	Copper (Cu)	Zinc (Zn)	Aluminum (Al)	Radium (Ra)
Jan. 24, 1951	13	2.2	13	16	68	28	160	54	68	1.6	0.0	370	1,210	35	7.54	------	6.0	------	------	1.0	------

NOTE.—Oxygen consumed 20; Mn 0.0; nitrite (NO_2) 0.021; ammonia nitrogen (NH_3) 402.

Special sample 2

[Prepared by filtering a mixture of 2 gals of distilled water and 3 gals of topsoil dug from a typical potato field]

Date collected	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Specific conductance ($K \times 10^6$)	Color	pH 1st	pH 2d	Phosphate (PO_4)	Copper (Cu)	Zinc (Zn)	Aluminum (Al)	Radium (Ra)
Jan. 24, 1951	12	0.60	132	19	15	19	0	268	98	0.3	153	743	930	25	4.5	------	0.1	------	------	4.6	------

NOTE.—Mn 0.0; NO_2 0.009; NH_4 22.

WATER CONSIDERED TO BE CONTAMINATED BY CESSPOOL EFFLUENT

Well S742

[W. de Laguna. Cliff Road, Wildwood, Wading River. Domestic well; Casing 4 in., well point 2 in., depth 90 ft, depth to water 80 ft. About 8 miles northeast of reactor]

Date collected	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Specific conductance ($K \times 10^6$)	Color	pH 1st	pH 2d	Phosphate (PO_4)	Copper (Cu)	Zinc (Zn)	Aluminum (Al)	Radium (Ra)
Mar. 3. 1953	10	11	7.3	4.5	15	3.3	18	21	22	0.0	9.7	104	162	3	6.3	------	0.0	------	0.09	0.1	------

NOTE.—Fe. dissolved 0.03; lithium (Li) 0.3; Mn, dissolved 0.05; Mn total 0.07; NO_2 1.7; NH_3 0.0.

Well S2815

[Vitobello. Chichester Ave., Center Moriches. Domestic well: Diameter 2 in., depth unknown, depth to water about 35 ft. About 4.5 miles southeast of reactor]

Date collected	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Specific conductance ($K \times 10^6$)	Color	pH 1st	pH 2d	Phosphate (PO_4)	Copper (Cu)	Zinc (Zn)	Aluminum (Al)	Radium (Ra)
Mar. 3, 1950	6.9	.42	3.6	3.1	7.9	1.2	9	6.4	12	0.0	13	61	103	5	6.3	------	0	0	4.5	0.3	0.38
Mar. 5, 1951	------	------	------	------	------	------	------	------	9	------	Tr.	------	91.7	------	------	------	------	------	------	------	------
Apr. 16 1951	------	------	------	------	------	------	------	------	8	------	Tr.	------	74.0	------	6.5	------	------	------	------	------	------
Aug. 8, 1951	------	------	------	------	------	------	------	------	8	------	Tr.	------	68.8	------	6.3	------	------	------	------	------	------
Dec. 3, 1951	------	------	------	------	------	------	------	------	8	------	5	------	76.0	------	6.6	------	------	------	------	------	------
Apr. 25, 1952	------	------	------	------	------	------	------	------	9	------	20	------	114	------	6.8	7.6	------	------	------	------	------
Aug. 8, 1952	------	------	------	------	------	------	------	------	8	------	15	------	91.0	------	6.7	7.4	------	------	------	------	------
Nov. 21, 1952	------	------	------	------	------	------	------	------	6	------	10	------	73.0	------	6.3	7.2	------	------	------	------	------
Feb. 16, 1953	------	------	------	------	------	------	------	------	8	------	20	------	92.2	------	6.3	7.2	------	------	------	------	------

Well S7144

[Town of Brookhaven. Police substation, Route 27, Center Moriches. Domestic well: Diameter 2 in., depth 40 ft, depth to water about 20 ft. About 6 miles southeast of reactor]

Feb. 13, 1950	8.4	2.0	18	5.7	29	4.4	3	20	50	0.1	52	208	360	2	4.9	------	0	0	1.2	0.6	0.36
Feb. 5, 1951	------	------	------	------	------	------	------	------	48	------	55	------	347	------	------	------	------	------	------	------	------
Apr. 16, 1951	------	------	------	------	------	------	------	------	37	------	100	------	439	------	4.7	------	------	------	------	------	------
July 27, 1951	------	------	------	------	------	------	------	------	32	------	60	------	346	------	4.8	------	------	------	------	------	------
Nov. 26, 1951	------	------	------	------	------	------	------	------	29	------	45	------	273	------	5.4	------	------	------	------	------	------
Apr. 18, 1952	------	------	------	------	------	------	------	------	39	------	60	------	350	------	4.8	4.5	------	------	------	------	------
Aug. 8, 1952	------	------	------	------	------	------	------	------	29	------	60	------	340	------	4.7	4.5	------	------	------	------	------
Nov. 14, 1952	------	------	------	------	------	------	------	------	23	------	60	------	312	------	4.7	4.4	------	------	------	------	------
Feb. 16, 1953	------	------	------	------	------	------	------	------	18	------	55	------	243	------	4.8	4.3	------	------	------	------	------

WATER CONSIDERED TO BE CONTAMINATED BY FERTILIZER

Well S9140

[Ferris Talmadge. Long Lane, Easthampton. Domestic well: Diameter 1½ in., depth 60 ft. About 36 miles east of reactor]

Dec. 14, 1949	------	------	------	------	------	------	12	37	30	------	20	------	233	2	6.2	------	------	------	------	------	------

Well S5341

[Long Island Vegetable Research Farm. Sound Ave., Riverhead. Domestic well, diameter 2 in. depth 125 feet, depth to water 92 ft. About 11 miles northeast of reactor]

Apr. 13, 1948	7.4	0.83	29	8.1	17	2.7	9	72	20	0.0	43	206	329	3	6.2	------	0	0	0	0	------
June 17, 1948	7.6	.17	28	7.9	18	3.8	8	71	19	.1	38	197	320	1	7.0	------	0	0	0	0	1.66
Apr. 4, 1949	8.4	.75	30	8.3	22	4.8	9	79	23	.0	47	251	365	1	6.0	------	0	0	0	0	------
Dec. 14, 1949	------	------	------	------	------	------	10	83	24	------	42	------	364	1	7.1	------	------	------	------	------	------

Well S9139

[E. Wiggins. 0.5 mile west of East Marion, on North Road. Domestic well: Diameter 2 in., depth 25 ft. About 33 miles east of reactor]

Dec. 14, 1949	------	------	------	------	------	------	12	70	18	------	50	------	330	4	6.9	------	------	------	------	------	------

Well S9138

[E. E. Boisseau. Southold. Domestic well, diameter 2 in, depth 35 ft. About 27 miles northeast of reactor. This water may also be contaminated by a cesspool]

Dec. 14, 1949	------	------	------	------	------	------	0	95	42	------	115	------	574	1	4.6	------	------	------	------	------	------

TABLE 6.—*Chemical analyses of ground and surface water in and near Brookhaven National Laboratory, Suffolk County, N.Y.*—Con.

HIGH NITRATE GROUND WATER FROM UPPER PLEISTOCENE DEPOSITS—Continued

WATER CONSIDERED TO BE CONTAMINATED BY FERTILIZER—Continued

Well N2403

[In Levittown, Town of Hempstead, Nassua County. Public supply well: Diameter 12 in., depth 84 ft, nominal capacity 500 gpm. About 40 miles west of reactor]

Date collected	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Specific conductance ($K \times 10^5$)	Color	pH		Phosphate (PO_4)	Copper (Cu)	Zinc (Zn)	Aluminum (Al)	Radium (Ra)
															1st	2d					
Jan. 21, 1952	9.1	0.04	45	7.3	15	2.6	9	96	22	0.0	46	247	389	5	6.8	------	--------	------	------	--------	------

Well N2581

[In Levittown, Town of Hempstead, Nassau County. Public-supply well: Diameter 12 in., depth 81 ft, nominal capacity 800 gpm. About 40 miles west of reactor]

Date collected	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Specific conductance ($K \times 10^5$)	Color	pH		Phosphate (PO_4)	Copper (Cu)	Zinc (Zn)	Aluminum (Al)	Radium (Ra)
															1st	2d					
Jan. 21, 1952	9.1	0.10	37	4.4	16	30.0	12	68	20	.0	51	234	333	3	6.5	------	--------	------	------	--------	------

GROUND WATER FROM FORMATIONS OF CRETACEOUS AGE

Well S6456

[In Laboratory tract. Test well: Diameter 4 in., depth 220 ft, depth to water 48 ft. Well screened in upper part of Magothy(?) Formation, just below Gardiners Clay. About 2,200 ft west of reactor.]

Date collected	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Specific conductance ($K \times 10^5$)	Color	pH		Phosphate (PO_4)	Copper (Cu)	Zinc (Zn)	Aluminum (Al)	Radium (Ra)
															1st	2d					
Sept. 13, 1949	33	1.4	19	3.6	6.8	1.4	80	0.9	7.1	0.1	0.5	113	150	4	7.6	------	0.3	0	0	0.6	1.07

Well S6434

[In Laboratory tract. Test well 2: Diameter 10 in., depth to water 51 ft. Sample from temporary screen setting at 675 ft, in approximate middle of Magothy(?) Formation. About 800 ft north of reactor]

Date collected	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Specific conductance ($K \times 10^5$)	Color	pH		Phosphate (PO_4)	Copper (Cu)	Zinc (Zn)	Aluminum (Al)	Radium (Ra)
															1st	2d					
Jan. 25, 1949	12	2.8	4.3	1.3	3.8	1.0	18	4.3	3.8	0.0	0.1	38	52.0	25	7.1	------	0	0	0	.4	0.69

Well S6434

[Sample from final screen setting at depth of 1,392 ft. Water is from Lloyd sand member of Raritan Formation]

June 2, 1949	8.4	.47	4.3	2.7	7.2	2.4	24	12	5.6	.2	.1	53	90.7	3	6.5	------	.8	0	0	.5	1.13

Well S6409

[In Laboratory tract. Test well 1: Diameter 8 in. Sample from screen setting at 1,434 ft. Water is from Lloyd sand member of Raritan Formation. About 1.4 miles southwest of reactor]

Nov. 8, 1948	7.5	1.3	1.5	1.6	4.4	2.2	16	3.5	4.1	.1	.1	32	49.6	1	6.4	------	0	0	0	.1	1.28

SURFACE WATER FROM RIVERS

Peconic River at Schultz Road (Wading River-Center Moriches Road)

[About 2.5 miles east of reactor. No ducks upstream]

Apr. 29, 1948	4.1	0.02	1.9	1.1	4.3	0.6	4	6.3	6.0	0.0	0.2	40	44.8	------	5.6	------	------	0	0	0.2	------
Mar. 29, 1949	1.1	.05	1.6	1.3	4.0	.9	3	5.7	6.9	.0	.2	36	46.0	70	5.1	------	0	0	0	.2	3.26
Mar. 5, 1951	------	------	------	------	------	------	------	------	8	------	0	------	72.6	------	------	------	------	------	------	------	------
June 1, 1951	------	------	------	------	------	------	------	------	7	------	0	------	53.8	------	6.2	------	------	------	------	------	------
Sept. 10, 1951	------	------	------	------	------	------	------	------	6	------	0	------	66.4	------	6.8	------	------	------	------	------	------
Feb. 12, 1952	------	------	------	------	------	------	------	------	6	------	0	------	59.0	------	5.8	6.4	------	------	------	------	------
June 11, 1952	------	------	------	------	------	------	------	------	6	------	0	------	60.8	------	5.9	6.7	------	------	------	------	------
Sept. 18, 1952	------	------	------	------	------	------	------	------	6	------	0	------	57.3	------	6.1	7.1	------	------	------	------	------
Dec. 23, 1952	------	------	------	------	------	------	------	------	6	------	0	------	59.6	------	6.1	6.8	------	------	------	------	------
Mar. 16, 1953	------	------	------	------	------	------	------	------	4	------	0	------	41.5	------	5.1	5.7	------	------	------	------	------

Peconic River at Edwards Ave., Calverton

[About 8 miles east of reactor. Several small duck farms upstream]

Mar. 29, 1949	4.0	0.30	2.8	1.1	4.4	1.2	0	7.8	11	0.0	0.5	47	85.4	35	4.25(?)	------	0.1	0	0	2.2(?)	0.62
Mar. 5, 1951	------	------	------	------	------	------	------	------	8	------	0	------	66.1	------	------	------	------	------	------	------	------
June 1, 1951	------	------	------	------	------	------	------	------	7	------	Tr.	------	65.4	------	6.2	------	------	------	------	------	------
Sept. 10, 1951	------	------	------	------	------	------	------	------	8	------	Tr.	------	88.6	------	6.5	------	------	------	------	------	------
Feb. 12, 1952	------	------	------	------	------	------	------	------	6	------	0	------	59.7	------	6.3	6.8	------	------	------	------	------
June 11, 1952	------	------	------	------	------	------	------	------	7	------	5	------	62.6	------	6.0	6.7	------	------	------	------	------
Sept. 18, 1952	------	------	------	------	------	------	------	------	7	------	Tr.	------	77.8	------	6.3	7.0	------	------	------	------	------
Dec. 17, 1952	------	------	------	------	------	------	------	------	6	------	Tr.	------	75.9	------	6.3	7.1	------	------	------	------	------
Mar. 16, 1953	------	------	------	------	------	------	------	------	5	------	0	------	48.3	------	6.4	7.0	------	------	------	------	------

TABLE 6.—*Chemical analyses of ground and surface water in and near Brookhaven National Laboratory, Suffolk County, N.Y.*—Con.

Date collected	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Specific conductance ($K \times 10^6$)	Color	pH		Phosphate (PO_4)	Copper (Cu)	Zinc (Zn)	Aluminum (Al)	Radium (Ra)
															1st	2d					
SURFACE WATER FROM RIVERS—Continued																					
Peconic River at Riverhead																					
[U.S. Geological Survey gaging station. About 11 miles east of reactor. A few duck farms upstream]																					
Apr. 14, 1948	3.5	0.14	4.4	1.6	5.0	1.3	8	8.8	7.2	0.0	3.6	49	78.6	44	6.0	------	------	0	0	0.2	------
June 17. 1948	8.3	.53	5.7	1.8	5.2	1.7	14	7.9	7.1	.0	4.1	60	74.4	90	6.8	------	0.1	0	0	.6	------
Oct. 7, 1948	9.0	.03	6.4	2.1	6.4	2.0	16	9.1	8.1	.1	4.5	59	86.8	8	6.7	------	.1	0	0	.1	449(?)
Jan. 11, 1949	4.7	.07	4.3	1.7	5.2	1.4	9	9.9	7.2	.0	2.3	47	65.7	45	6.2	------	0	0	0	.2	1.86
Mar. 29, 1949	------	------	------	------	------	------	9	10	7.0	.0	1.4	------	66.6	18	6.4	------	0	0	0	------	2.14
Nov. 13, 1950	------	------	------	------	------	------	------	------	8	------	Tr.	------	92.0	------	------	------	------	------	------	------	------
Mar. 5, 1951	------	------	------	------	------	------	------	------	8	------	0	------	75.1	------	------	------	------	------	------	------	------
May 28, 1951	------	------	------	------	------	------	------	------	7	------	Tr.	------	89.2	------	6.8	------	------	------	------	------	------
Sept. 10, 1951	------	------	------	------	------	------	------	------	8	------	0	------	89.1	------	7.2	------	------	------	------	------	------
Jan. 25, 1952	------	------	------	------	------	------	------	------	7	------	5	------	75.9	------	6.7	------	------	------	------	------	------
June 17, 1952	------	------	------	------	------	------	------	------	7	------	5	------	83.7	------	6.5	7.3	------	------	------	------	------
Sept. 18, 1952	------	------	------	------	------	------	------	------	7	------	5	------	84.3	------	6.2	7.4	------	------	------	------	------
Dec. 17, 1952	------	------	------	------	------	------	------	------	6	------	Tr.	------	83.0	------	6.6	7.3	------	------	------	------	------
Mar. 16, 1953	------	------	------	------	------	------	------	------	6	------	0	------	72.1	------	6.9	7.3	------	------	------	------	------
Terrell Pond at outlet																					
[Ponded reach of Terrell River. Route 27, East Moriches. About 8 miles southeast of reactor. No duck farms upstream]																					
Feb. 13, 1950	7.6	0.14	2.5	1.6	4.7	0.8	10	5.0	6.2	0.0	0.3	32	47.1	5	6.9	------	0	0.1	0	0	0.41
Feb. 5, 1951	------	------	------	------	------	------	------	------	7	------	0	------	50.7	------	------	------	------	------	------	------	------
Apr. 16, 1951	------	------	------	------	------	------	------	------	6	------	0	------	51.3	------	6.6	------	------	------	------	------	------
July 27, 1951	------	------	------	------	------	------	------	------	6	------	0	------	50.0	------	6.7	------	------	------	------	------	------
Nov. 26, 1951	------	------	------	------	------	------	------	------	6	------	0	------	46.8	------	7.0	------	------	------	------	------	------
Apr. 18, 1952	------	------	------	------	------	------	------	------	7	------	0	------	49.8	------	7.0	7.2	------	------	------	------	------
Aug. 1, 1952	------	------	------	------	------	------	------	------	6	------	0	------	51.1	------	6.8	7.2	------	------	------	------	------
Nov. 14, 1952	------	------	------	------	------	------	------	------	5	------	0	------	50.6	------	6.9	6.9	------	------	------	------	------
Feb. 9, 1953	------	------	------	------	------	------	------	------	4	------	0	------	49.0	------	6.9	7.2	------	------	------	------	------

Forge River, West Branch

[At Route 27, Moriches. About 4.5 miles south of reactor. Large duck farms upstream]

Apr. 29, 1948	9.9	0.02	8.1	2.6	6.3	4.2	13	7.0	8.8	0.3	22	93	114		6.0		5.1	0	0	0.1	

Forge River, East Branch

[At Route 27, Moriches. About 4.5 miles south of reactor. Large duck farms upstream]

Apr. 29, 1948	10	0.01	10	3.4	6.5	4.6	8	9.4	8.8	0.4	40	112	141		5.2		8.0	0	0	0.2	

Forge River below confluence of east and west branches

[At Route 27, Moriches. About 4.5 miles south of reactor. Large duck farms upstream]

Jan. 11, 1949	8.4	0.01	6.0	2.4	5.7	2.6	12	7.2	7.5	0.0	14	63	92.5	4	6.1		1.5	0	0	0	1.18
Mar. 29, 1949	9.7	.02	7.4	2.1	6.7	2.2	10	7.3	7.2	.1	20	77	100	10	6.0		2.6	0	0	.3	3.41
Dec. 5, 1950									10		15		119								
Apr. 16, 1951									9		0		173		6.4						
July 20, 1951									9		0		199		6.9						
Oct. 29, 1951									8		0		132		6.6						
Dec. 28, 1951									8		20		112		6.3						
Apr. 11, 1952									8		0		152		6.9	7.4					
Aug. 1, 1952									8		0		177		6.7	6.7					
Nov. 7, 1952									7		15		101		6.4	7.3					
Feb. 2, 1953									6		10		109		7.0	7.2					

Carmans River at Yaphank

[U.S. Geological Survey gaging station. About 3 miles southwest of reactor. No duck farm upstream]

Apr. 14, 1948	10	0.03	5.2	2.1	4.8	0.9	15	8.4	6.6	0.0	2.2	49	72.5	8	6.5		0	0	0		
June 17, 1948	11	.03	5.3	2.1	4.8	.9	17	9.1	6.5	.1	2.1	50	71.5	6	7.3		.1	0	0	0	
Oct. 7, 1948	12	.02	5.6	2.3	4.9	1.0	16	8.8	7.0	.1	2.0	51	74.6	2	6.9		0	0	0	.2	
Jan. 11, 1949	10	.02	5.2	2.1	5.3	1.1	14	9.2	6.8	.0	2.9	52	74.4	10	6.8		0	0	0	0	
Mar. 29, 1949	10	.04	5.6	2.3	4.4	1.5	16	8.6	6.6	.0	3.1	51	81.1	5	6.7		0	0	0	.1	1.84
Dec. 18, 1950									7		Tr.		80.8								
Apr. 5, 1951									7		Tr.		76.2								
July 6, 1951									7		Tr.		75.5		7.3						
Oct. 15, 1951									7		Tr.		77.8		7.0						
Apr. 4, 1952									7		Tr.		81.1		7.1	7.3					
July 18, 1952									6		Tr.		82.2		6.8	7.4					
Oct. 30, 1952									6		Tr.		79.6		6.7	7.5					
Jan. 26, 1953									6		Tr.		79.4		6.9	7.1					

TABLE 6.—*Chemical analyses of ground and surface water in and near Brookhaven National Laboratory, Suffolk County, N.Y.*—Con.

Date collected	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Specific conductance ($K \times 10^5$)	Color	pH		Phosphate (PO_4)	Copper (Cu)	Zinc (Zn)	Aluminum (Al)	Radium (Ra)
															1st	2d					
SURFACE WATER FROM RIVERS—Continued																					
Carmans River [At Route 27, South Haven. About 5 miles south of reactor. No duck farm upstream]																					
Feb. 13, 1950	1.5	0.18	4.8	2.3	4.7	1.0	18	8.1	6.5	0.0	1.5	47	68.2	1	6.7	------	0	0	0	0.1	1.79
Nov. 24, 1950	------	------	------	------	------	------	------	------	6	------	0	------	73.3	------	------	------	------	------	------	------	------
Apr. 5, 1951	------	------	------	------	------	------	------	------	6	------	0	------	67.5	------	------	------	------	------	------	------	------
July 6, 1951	------	------	------	------	------	------	------	------	6	------	0	------	68.4	------	9.3	------	------	------	------	------	------
Oct. 15, 1951	------	------	------	------	------	------	------	------	6	------	0	------	65.4	------	7.1	------	------	------	------	------	------
Apr. 4, 1952	------	------	------	------	------	------	------	------	6	------	0	------	72.8	------	7.0	7.6	------	------	------	------	------
July 18, 1952	------	------	------	------	------	------	------	------	6	------	0	------	74.7	------	6.8	7.6	------	------	------	------	------
Oct. 30, 1952	------	------	------	------	------	------	------	------	5	------	Tr.	------	71.1	------	7.2	7.5	------	------	------	------	------
Jan. 26, 1953	------	------	------	------	------	------	------	------	5	------	Tr.	------	72.2	------	7.0	7.0	------	------	------	------	------
Beaverdam Creek [In Brookhaven. At Beaverdam Road. About 7 miles south of reactor. No duck farms upstream]																					
Apr. 29, 1948	8.6	0.01	2.4	1.3	4.6	0.6	10	5.6	6.1	0.1	0.2	36	48.1	------	6.5	------	0.1	0	0	0.1	------
Bellport Creek [At Route 27, Bellport. About 7 miles southwest of reactor. Large laundry upstream]																					
May 14, 1948	11	0.02	5.4	1.8	10	1.4	24	9.8	7.8	0.4	4.2	65	95.6	18	7.2	------	0.2	0	0	0.1	------
Mud Creek [At Route 27, East Patchogue. About 9 miles southwest of reactor. Duck farm upstream]																					
May 14, 1948	8.9	0.01	7.0	2.7	6.1	3.7	9	8.1	9.2	0.3	20	75	105	8	5.7	------	5.5	0	0	0	------

Swan River

[At Route 27, East Patchogue. About 10 miles southwest of reactor. No duck farm upstream]

Apr. 15, 1948	9.1	0.02	3.2	1.5	4.1	0.7	11	5.2	5.1	0.1	0.7	37	49.3	20	6.6	------	0	0	0	--------	------

Patchogue Creek

[At Route 27, Patchogue. About 10 miles southwest of reactor. No duck farm upstream]

May 14, 1948	8.3	0.01	3.2	1.5	5.7	1.0	13	7.7	5.8	0.1	0.7	39	58.9	4	7.2	------	0.1	0	0	0	------

Tuthills Creek

[At Route 27, Patchogue. About 10 miles southwest of reactor. No duck farm upstream]

May 25, 1948	7.1	0.10	2.1	1.2	4.1	0.6	9	5.6	4.9	0.1	0.3	29	41.4	7	6.8	------	0	0	0	0	------

Rattlesnake Brook

[At Route 27, Oakdale. About 17 miles southwest of reactor. No duck farm upstream]

May 25, 1948	8.9	0.01	2.9	2.0	3.9	0.7	15	4.2	4.8	0.1	0.3	34	48.3	16	7.0	------	0	0	0	0.1	------

Connetquot Brook

[At Route 27, Oakdale. About 17 miles southwest of reactor. No duck farm upstream]

Apr. 15, 1948	9.2	0.02	3.1	1.9	3.9	0.6	15	4.4	4.8	0.0	0.5	38	50.9	34	6.8	------	0	0	0	--------	------
June 17, 1948	8.8	.01	2.6	1.7	3.9	.7	14	4.0	4.9	.1	.4	34	45.2	15	6.7	------	0	0	0	0	------

Champlin Creek

[At Moffitt Blvd., Islip. About 19 miles west of reactor. No duck farm upstream]

May 14, 1948	8.8	0.01	4.3	1.9	5.0	1.0	7	12	6.1	0.1	4.0	52	70.8	------	6.2	------	0	0	0	0.1	------

TABLE 6.—*Chemical analyses of ground and surface water in and near Brookhaven National Laboratory, Suffolk County, N.Y.*—Con.

Date collected	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Specific conductance ($K\times10^5$)	Color	pH		Phosphate (PO_4)	Copper (Cu)	Zinc (Zn)	Aluminum (Al)	Radium (Ra)
															1st	2d					
SURFACE WATER FROM RIVERS—Continued																					
Nissequoque River																					
[At Route 25, Smithtown. About 17 miles west of reactor. No duck farm upstream]																					
Apr. 15, 1948	6.2	0.01	2.4	1.0	3.6	0.6	8	4.5	4.5	0.1	0.6	29	41.1	12	6.3	------	0	0	0	------	------
June 17, 1948	6.8	.02	2.7	1.2	4.2	.8	10	5.5	4.9	.1	.9	32	45.6	6	7.1	------	0	0	0	0.1	------
Wading River																					
[At Wading River Post Office. About 6 miles north of reactor. No duck farm upstream]																					
Apr. 29, 1948	9.0	0.10	3.1	1.6	5.6	0.6	12	6.5	7.8	0.0	0.5	40	59.7	------	6.8	------	0	0	0	0	------
SURFACE WATER FROM LAKES																					
Deep Pond (Lake Wauwepex)																					
[In Wading River. About 5 miles northeast of reactor]																					
Apr. 14, 1948	1.1	0.01	2.5	1.4	5.8	0.6	8	7.4	8.2	0.0	0.2	31	62.4	6	6.3	------	0	0	0	------	------
June 17, 1948	1.0	.01	3.0	1.4	5.7	.9	7	7.4	8.1	.1	.8	30	58.1	1	6.9	------	0	0	0	0	------
Dec. 16, 1950	------	------	------	------	------	------	------	------	10	------	0	------	73.5	------	------	------	------	------	------	------	------
Mar. 9, 1951	------	------	------	------	------	------	------	------	10	------	0	------	68.4	------	------	------	------	------	------	------	------
June 8, 1951	------	------	------	------	------	------	------	------	10	------	0	------	66.2	------	6.8	------	------	------	------	------	------
Sept. 21 1951	------	------	------	------	------	------	------	------	10	------	0	------	65.5	------	6.9	------	------	------	------	------	------
Feb. 29, 1952	------	------	------	------	------	------	------	------	8	------	0	------	64.0	------	7.0	7.2	------	------	------	------	------
June 17, 1952	------	------	------	------	------	------	------	------	8	------	0	------	64.8	------	6.6	7.4	------	------	------	------	------
Sept. 25, 1952	------	------	------	------	------	------	------	------	8	------	0	------	67.5	------	6.9	7.2	------	------	------	------	------
Dec. 23, 1952	------	------	------	------	------	------	------	------	7	------	0	------	69.8	------	7.0	7.2	------	------	------	------	------
Mar. 23, 1953	------	------	------	------	------	------	------	------	7	------	0	------	65.1	------	7.2	7.3	------	------	------	------	------

Long Pond (Lake Panamoka)

[In Wading River. About 4 miles northeast of reactor]

Apr. 14, 1948	0.7	0.01	2.2	1.1	3.5	0.4	6	5.5	5.0	0.0	0.0	22	41.2	4	6.4	------	0	0	0	------	------
June 17, 1948	.6	.01	2.7	1.1	3.7	.4	7	6.2	5.2	.1	.4	22	40.8	1	6.6	------	0	0	0	0	------
Oct. 7, 1948	1.7	.01	2.9	1.2	4.2	.7	8	6.5	5.9	.1	.4	26	49.1	3	6.3	------	0	0	0	0	3.06
Jan. 11, 1949	1.6	.01	1.9	1.0	3.8	1.3	5	5.6	5.4	.1	.2	24	45.5	3	6.5	------	0	0	0	.1	------

Artist Lake

[At Middle Island. About 3 miles northwest of reactor]

Apr. 14, 1948	0.5	0.02	2.6	0.8	3.2	0.8	2	8.4	5.2	0.0	0.0	24	44.0	4	5.7	------	0	0	0	------	------
June 18, 1948	.3	.01	3.1	.9	3.5	.9	3	8.2	5.2	.2	.8	23	46.1	2	5.3	------	0	0	0	0	------
Oct. 7, 1948	.5	.01	3.3	1.0	3.2	.9	4	9.1	5.5	.1	.2	28	52.0	1	6.1	------	0	0	0	0	------
Jan. 11, 1949	.2	.01	2.6	.8	3.4	1.2	2	7.7	5.5	.0	.4	23	44.2	1	5.7	------	0	0	0	0	------
Dec. 18, 1950	------	------	------	------	------	------	------	------	9	------	0	------	58.8	------	------	------	------	------	------	------	------
Mar. 9, 1951	------	------	------	------	------	------	------	------	9	------	0	------	54.7	------	------	------	------	------	------	------	------
June 8, 1951	------	------	------	------	------	------	------	------	9	------	0	------	55.3	------	6.1	------	------	------	------	------	------
Sept. 21, 1951	------	------	------	------	------	------	------	------	9	------	0	------	59.4	------	6.1	------	------	------	------	------	------
Dec. 17, 1951	------	------	------	------	------	------	------	------	7	------	0	------	57.7	------	6.0	------	------	------	------	------	------
Feb. 29, 1952	------	------	------	------	------	------	------	------	6	------	0	------	52.3	------	6.0	6.2	------	------	------	------	------
June 27, 1952	------	------	------	------	------	------	------	------	7	------	0	------	54.6	------	6.1	6.9	------	------	------	------	------
Sept. 25, 1952	------	------	------	------	------	------	------	------	6	------	0	------	52.3	------	6.2	6.4	------	------	------	------	------
Dec. 30, 1952	------	------	------	------	------	------	------	------	6	------	0	------	59.2	------	6.0	6.5	------	------	------	------	------
Feb. 23, 1953	------	------	------	------	------	------	------	------	6	------	0	------	49.0	------	6.2	6.9	------	------	------	------	------

Lake Ronkonkoma

[In Smithtown. About 13 miles west of reactor]

Apr. 29, 1948	1.5	0.01	2.4	1.1	4.1	0.8	5	8.2	5.8	0.0	0.5	28	46.6	------	7.1	------	0.1	0	0	0.1	------
June 17, 1948	.8	.01	2.8	1.1	3.9	1.0	6	8.2	5.8	.1	.4	25	46.1	2	6.0	------	0	0	0	0	------

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