Water-Supply and Irrigation Paper No. 144

Series L, Quality of Water, 10

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

THE NORMAL DISTRIBUTION OF CHLORINE IN THE NATURAL WATERS OF NEW YORK AND NEW ENGLAND

BY

DANIEL D. JACKSON

WASHINGTON

GOVERNMENT PRINTING OFFICE

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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
HYDROGRAPHIC BRANCH,
Washington, D. C., December 20, 1904.

SIR: I transmit herewith a manuscript entitled "The Normal Distribution of Chlorine in the Natural Waters of New York and New England," by Daniel D. Jackson, and request that it be published in the series of Water-Supply and Irrigation Papers.

There is probably no more important feature involved in the establishment of municipal water supplies in States bordering on or situated close to the seacoast than the determination of normal chlorine. The availability of any water for such purposes depends largely upon its freedom from organic contamination. Chlorine is one of the ingredients of dangerous organic matter, and, as this element is extremely stable, it undergoes none of the chemical changes common to the other component parts of organic matter, and its determination furnishes reliable and persistent evidence concerning the pollution of any water.

A certain proportion of the chlorine in a water has its origin in natural causes, and has no relation to artificial pollution; therefore, in determining the character of a water for domestic purposes, it is necessary to consider this natural or normal chlorine, and whenever the chlorine present is in excess of the normal the evidence of past pollution is complete.

It has been found, moreover, that (with the exception of local deposits) the normal chlorine in natural waters is derived from the salt of the ocean, blown over the land by storms, and that it diminishes in amount as the distance from the ocean increases. This decrease is so definite that equal amounts of chlorine are found along lines generally parallel to the seacoast, thus affording a basis for the establishment of isochlors. In Massachusetts and Connecticut these lines have been located, and for several years the information has proved to be of great value to the water-supply interests of those States. The accompanying paper extends this information to the remainder of the New England States and to New York.

Very respectfully,

F. H. NEWELL,
Chief Engineer.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

THE NORMAL DISTRIBUTION OF CHLORINE IN THE NATURAL WATERS OF NEW YORK AND NEW ENGLAND.

By Daniel D. Jackson.

INTRODUCTION.

Chlorine, a constituent of common salt, is present in nearly all natural waters. Its original sources are mineral salt deposits and finely divided salt spray from the sea. This latter is carried with dust particles by the wind and precipitated with the rain. All salt found in waters not coming from these original sources comes from domestic drainage and indicates that the water either is at the present time polluted or was polluted and has since been purified. By a comparison of the salt content of any water under examination with the normal chlorine figure for that region the extent of past or present pollution may be determined.

PHYSIOLOGICAL FUNCTIONS OF COMMON SALT.

Salt always occurs in drainage from animal sources, because in all animal economy a certain fairly definite amount of common salt is eaten with the food daily and later expelled from the body in practically the same condition in which it was absorbed. That it plays an important rôle in the blood is indicated by the fact that on an average it constitutes about one-half of the total blood ash. It is also found that normal gastric juice can not be formed without the presence of salt, and that in many other secretions of the body its presence is probably a necessity.

SALT AS AN INDICATION OF POLLUTION.

The amount of salt in a water is a valuable indication of pollution because of the following facts: (1) The animal body expels the same amount of salt that it absorbs; (2) this salt is unchangeable in the soil and is very soluble in water; (3) it must eventually form a part of the drainage and become mixed with the general run-off of the region in which it is expelled. The average amount of salt entering the drainage of any particular district is so constant for each inhabitant that it has been claimed that the number of people living on a drainage area may be determined with a fair degree of accuracy from the average run-off and the excess of chlorine over the normal. Stearns[a] estimates the chlorine in the run-off of any drainage area not receiving factory waste to be increased about one-tenth of a part per million by every 20 inhabitants per square mile.

SALT IN THE WATERS OF INLAND STATES.

All salt in natural unpolluted waters farther inland than Ohio comes from mineral deposits. The salt winds from the sea have no effect beyond this State, but unfortunately west of this State a large proportion of the natural waters are more or less affected by the salt deposits. The underground salt seems to spread over a broad area and exerts not only a wide but a variable influence over most of the waters. In these inland States, while the "normal chlorine" would be practically zero the value of the determination of chlorine is in most cases vitiated by the variable quantity of salt from mineral sources. Determinations of chlorine in samples of water taken above and below a city which runs its drainage into the stream examined may give the extent of pollution due to the city sewage, but the waters so far analyzed in the inland States give indications that the question of *normal* chlorine does not to any great extent enter into sanitary problems.

SALT IN COAST STATE WATERS.

On the other hand, the coast State waters are practically unaffected by this mineral salt, and, while very extensive deposits exist, especially in the State of New York, they are in narrow pockets and exert an influence over a very limited area. Except in these pockets the mineral salt has apparently been washed into the sea.

It is found that in the coast States the salt in the natural waters which comes from original sources.is practically all brought in by the sea winds, and that a certain normal amount is present in the waters of each locality.

The difference in the normal amount in different localities is due to variations (1) in distance from the seacoast, (2) in the amount of rainfall, (3) in the rate of evaporation, (4) in the amount of protection from ocean winds, and (5) in the direction of the prevailing winds. In spite of the great variety of causes which affect the normal chlorine in natural waters, the normal for any particular region is surprisingly constant.

The chlorine decreases as waters farther and farther inland are tested, so that by connecting with lines on the map localities having the same normal we find that these lines of equal chlorine (isochlors) follow in a general way the coast lines, and as they extend inland are still more or

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[a] Stearns, F. P., Rept. Mass. State board of health, 1890, pt. 1, p. 680.

less parallel to the coast. The distance of these lines from the coast depends chiefly upon the general direction of the wind and the protecting influences of mountains on the coast or of islands near the mainland.

COLLECTION OF SAMPLES.

In order to obtain the normal chlorine lines for any State it is necessary to first collect a large number of analyses for chlorine in waters taken at different seasons over the entire area to be covered. It is evident that near the seacoast, where the variations in chlorine within a limited area are greatest, the largest number of data must be collected. A large number of samples of water taken from surface and ground sources must be obtained. The pond waters usually give the best results, and careful inspection of the drainage area of such sources gives a good idea of whether or not the water is subject to pollution. Samples for analysis should be chosen as far from human habitation as possible.

SOLUTIONS REQUIRED FOR CHLORINE DETERMINATIONS.

The following solutions are employed in the analysis of water for chlorine:

Salt solution.—A solution of chemically pure fused salt, containing 1 milligram of chlorine in each cubic centimeter is made by dissolving 1.648 grams of the fused sodium chloride in 1 liter of distilled water free from chlorine.

Silver nitrate solution.—Two and one-half grams of crystallized silver nitrate are dissolved in 1 liter of distilled water free from chlorine. To this solution water or strong silver nitrate is added until by actual titration 10 c. c. of it are equivalent to 5 c. c. of the standard salt solution. One cubic centimeter of this solution is then equivalent to 0.5 milligram of chlorine.

Potassium chromate solution.—An indicator solution is made by dissolving 50 grams of potassium chromate in 1 liter of distilled water and then adding sufficient silver-nitrate solution to precipitate all the chlorine present and turn the precipitate slightly reddish. This is allowed to stand, and (by filtering or decanting) the clear solution is then obtained.

Emulsion of alumina.—This is made by dissolving 125 grams of potassium or ammonium alum in 1 liter of water and precipitating the alumina from the boiling solution by ammonia. After precipitation the alumina must be washed free from chlorine, sulphate, and ammonia by successive treatments, settlings, and decantations with cold distilled water.

METHODS OF PROCEDURE IN THE DETERMINATION OF CHLORINE.

Pour 25 c. c. of the water to be tested into a white porcelain dish. Add about one-half a cubic centimeter of chromate solution and run in standard silver-nitrate solution from a burette until the first faint reddish tint appears. This is more easily noted if, for comparison, a dish containing the same amount of water and chromate is kept beside the dish in which the test is made.

If one or more cubic centimeters of silver nitrate are necessary to reach an end point, the test may be made without evaporation, but if less is required, then evaporate 250 c. c. to 25 c. c. volume before making the test. It may at times be necessary to evaporate more than this if the chlorine present is very close to zero in amount.

It is best to always titrate with 25 c. c. of the water. In this case 0.1 c. c. is subtracted from the results as an indicator error. If more than this amount is used in titration, subtract 0.1 c. c. for each 25 c. c. of the volume of water titrated.

If 250 c. c. of water are taken, the number of cubic centimeters of silver nitrate solution used to obtain an end point minus 0.1 c. c. multiplied by 2 gives the chlorine in parts per million.

Example: 250 c. c. are evaporated to a volume of 25 c. c. and chromate solution added. In the titration 3.5 c. c. of silver nitrate are used. Then $(3.5-0.1)\times 2=6.8$. The water then contains 6.8 parts per million of chlorine.

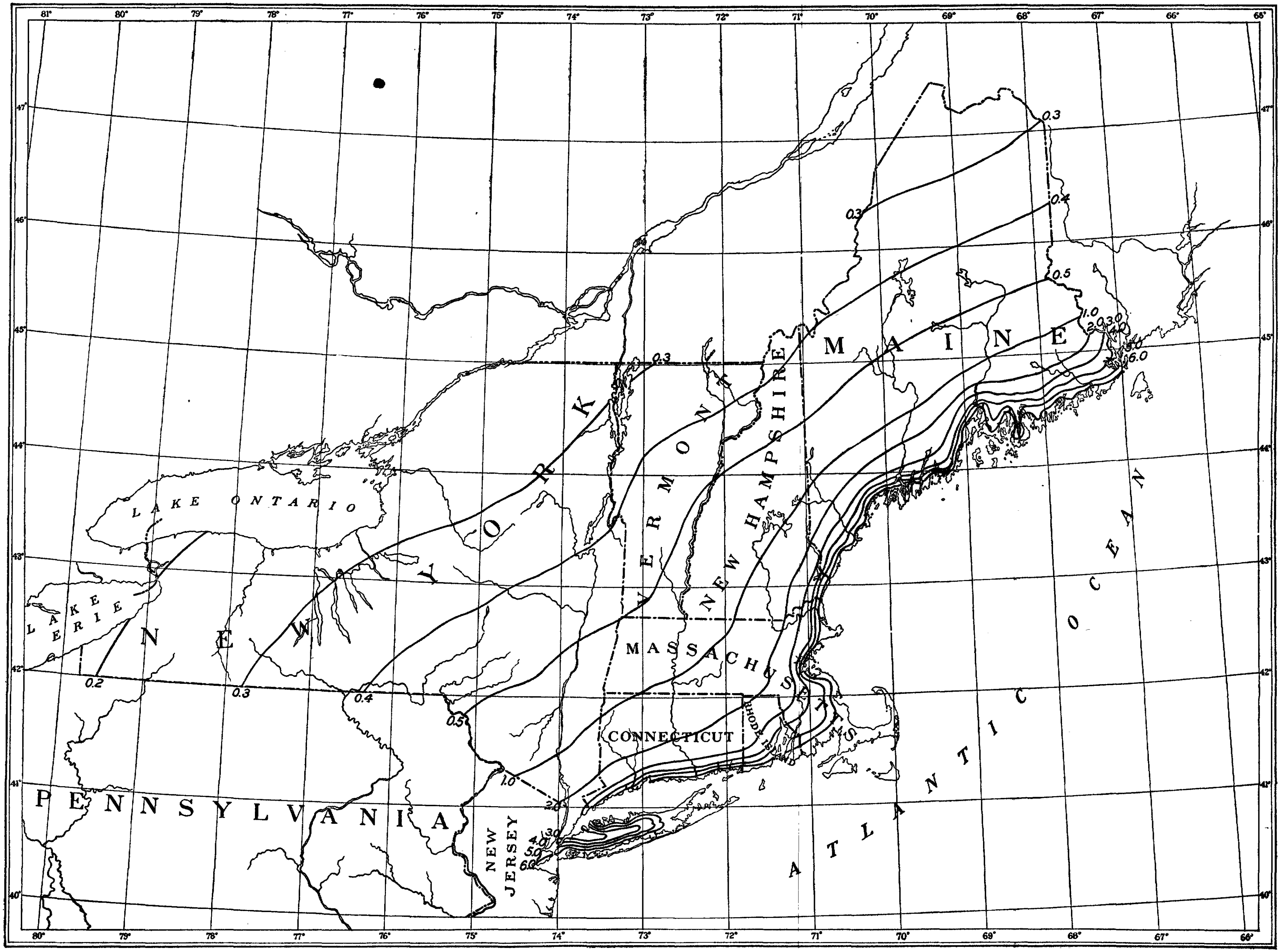
If the sample is highly colored and very turbid, it may be necessary to clarify it by treating it with an emulsion of alumina. This is best accomplished by bringing the water just to the boiling point, and then adding alumina and shaking the emulsion. In a few minutes the clarified water may be decanted. This is allowed to cool and the required amount is measured out for titration.

OBSERVATIONS ON THE USE OF THE NORMAL CHLORINE MAP.

Having drawn a map of this character for any coast State we are then able to estimate the pollution in any natural water by the amount of chlorine present over the normal. In some instances it is first necessary to ascertain that the chlorine is not from mineral sources.

It will be seen that the normal chlorine lines are of great practical value both to the chemist and to the engineer, as they give an index from which may be estimated the sanitary quality of most waters analyzed within the coast States. The chlorine also furnishes information as to the source of deep-seated springs or artesian wells.

While this chlorine in the general run-off is in direct proportion to the population on a drainage area, provided none of the sewage is carried outside of that area, yet waters in this region may have been puri-



NORMAL CHLORINE MAP OF NEW ENGLAND AND NEW YORK.

fied before reaching the source from which they are collected. The chlorine would still be present, and it is necessary to find from other tests whether the pollution is present or past.

HISTORY OF NORMAL CHLORINE WORK.

The first map of normal chlorine was made of the State of Massachusetts by the Massachusetts State board of health and published in their annual report of 1890. This was followed in 1895 by a normal chlorine map of Connecticut by the Connecticut State board of health, which map was revised in the report of that board for 1892. In 1898 a normal map of the island of Jamaica was published.[a] A similar map was published of Long Island, New York,[b] in 1900.

The boards of health and the geological surveys of many of the States have been working on the problem of normal chlorine for some period of time, but it has been found a difficult matter to establish these lines without having considerable data from adjoining States. The United States Geological Survey has considered it advisable, therefore, to collect the data from the various States and supplement the observations wherever it is required. In this way a connected map may be made for all of the coast States. The map herewith submitted is made up in this manner. While slight changes may be necessary as more observations are obtained, this map for New York and New England is thoroughly practical for sanitary purposes, and ought to be of great service in making sanitary surveys within this region. (See Pl. I.)

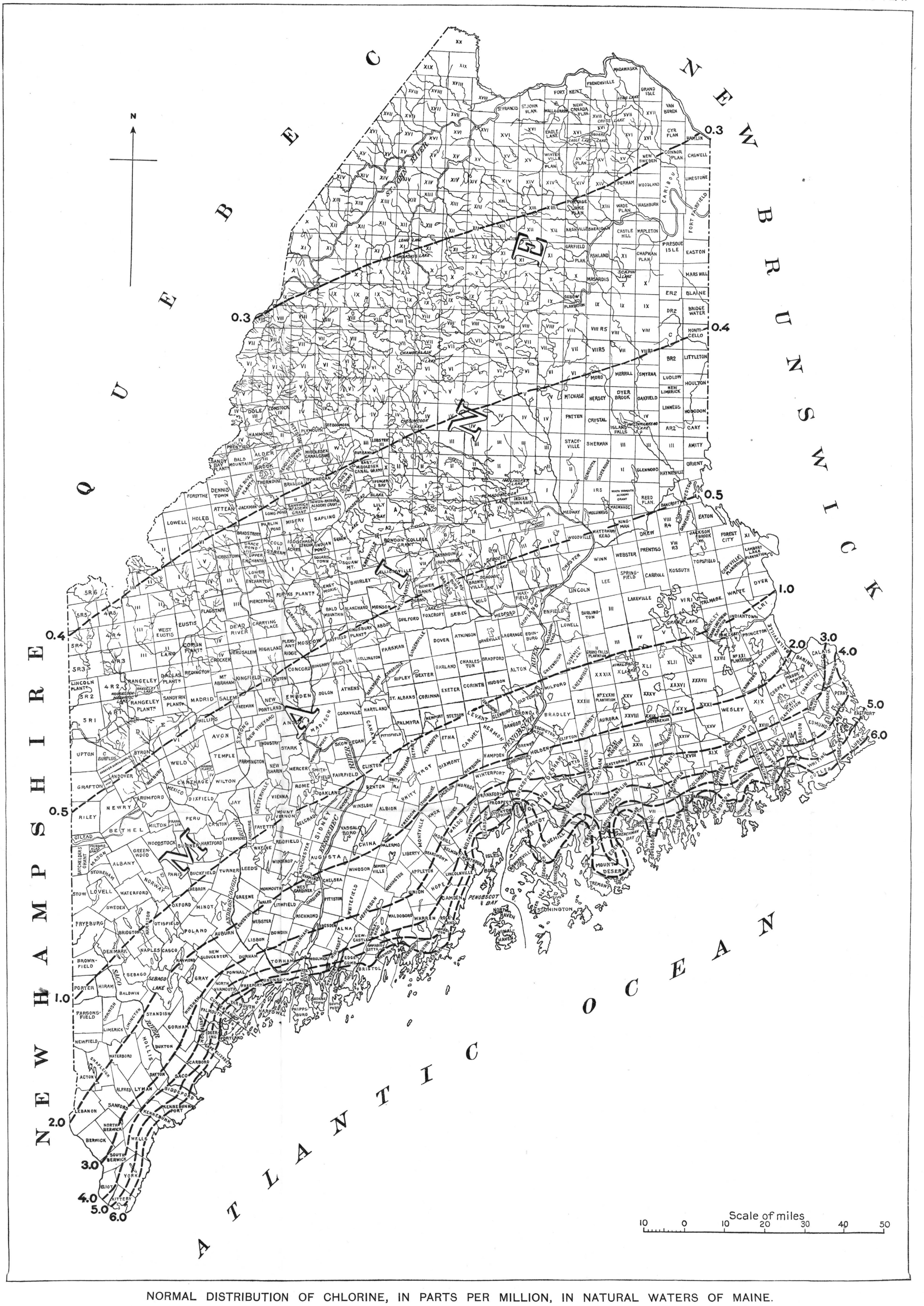
THE ISOCHLORS OF MAINE.

The normal chlorine lines of the State of Maine (Pl. II) have been made up from data published by the State board of health of Maine from sanitary surveys made by Mr. M. O. Leighton, chief of the division of hydro-economics, United States Geological Survey, by Prof. N. C. Grover, of the University of Maine, and by the author.

Maine presents such an extended and irregular coast line that the determination of the isochlors is attended with considerable difficulty. Irregularities in what would naturally be expected to be the position of the lines are in part due to the protecting influence of islands and in part to mountains near the seacoast.

The following list gives the amount of chlorine in those waters which have had a bearing upon the determination of isochlors for the State of Maine:

[a] Richards, Mrs. E. H., and Hopkins, Arthur T., Techn. Quart., vol. 11, no. 4, Dec., 1898.
[b] Whipple, Geo. C., and Jackson, Daniel D., Techn. Quart., vol. 13, no. 2, June, 1900, pp. 145–148.



NORMAL DISTRIBUTION OF CHLORINE, IN PARTS PER MILLION, IN NATURAL WATERS OF MAINE.

Chlorine determinations for Maine.

[Parts per million.]

Source.	Chlorine.
Androscoggin County:	
Auburn, Lake Auburn	2.0
Curtis Corner, spring	2.0
Lewiston, spring	2.0
well	2.0
Lisbon, spring	2.5
Livermore Falls, spring	.8
Mechanic Falls, spring	1.5
water supply	2.0
Sabattus, spring	2.0
Turner, well	2.0
West Minot, spring	2.0
Aroostook County:	
Caribou, well	.3
Fort Fairfield, spring	.3
Fort Kent, spring	.3
Houlton, spring	.4
Presque Isle, brook	.3
Cumberland County:	
Ash Cove, spring	6.0
Brunswick, spring	2.8
water supply	4.0
Deering, spring	4.0
East Baldwin, well	2.0
Gray, spring	2.5
Growstown, spring	5.2
North Raymond, spring	2.0
Portland, spring	6.0
Pownal, spring	6.0
Saccarappa, well	5.0
Scarboro, spring	6.0
Sebago, lake	2.0
well	2.0
Walnut Hill, well	5.0
West Baldwin, spring	1.5
Westbrook, spring	4.0
Yarmouth, spring	6.0
Yarmouthville, spring	5.0
Franklin County:	
Avon, pond	.8
Hancock County:	
Bar Harbor, Eagle Lake	[illegible] 0
Brooklin, spring	8.0
well	8.6
Brooksville, spring	6.0
Bucksport, well	0
Castine, spring	0
Lemoine, spring	0
Sedgwick, Black Pond	8
spring	6.8
spring	6.4
Upper Pond	6.5
Kennebec County:	
Augusta, well	2.0
Gardiner, spring	3.0
Manchester, well	1.5
Monmouth, spring	2.0
Riverside, spring	2.0
Waterville, China Lake	1.5
Messalonskie Lake	1.2
Messalonskie River	1.2
Tobey Stream	1.2
West Sidney, spring	2.0
Winslow, spring	2.0
Winthrop, well	2.0
well	2.0
Knox County:	
Camden, spring	4.0
Rockland, water supply	3.7
Thomasville, water supply	6.0
Union, spring	2.5
Warren, spring	4.0
Washington, spring	2.5
Lincoln County:	
Jefferson, stream	3.0
Waldoboro, well	4.0
Oxford County:	
Andover, spring	.5
Canton, well	1.0
Dixfield, small brook	.8

Chlorine determinations for Maine—Continued.

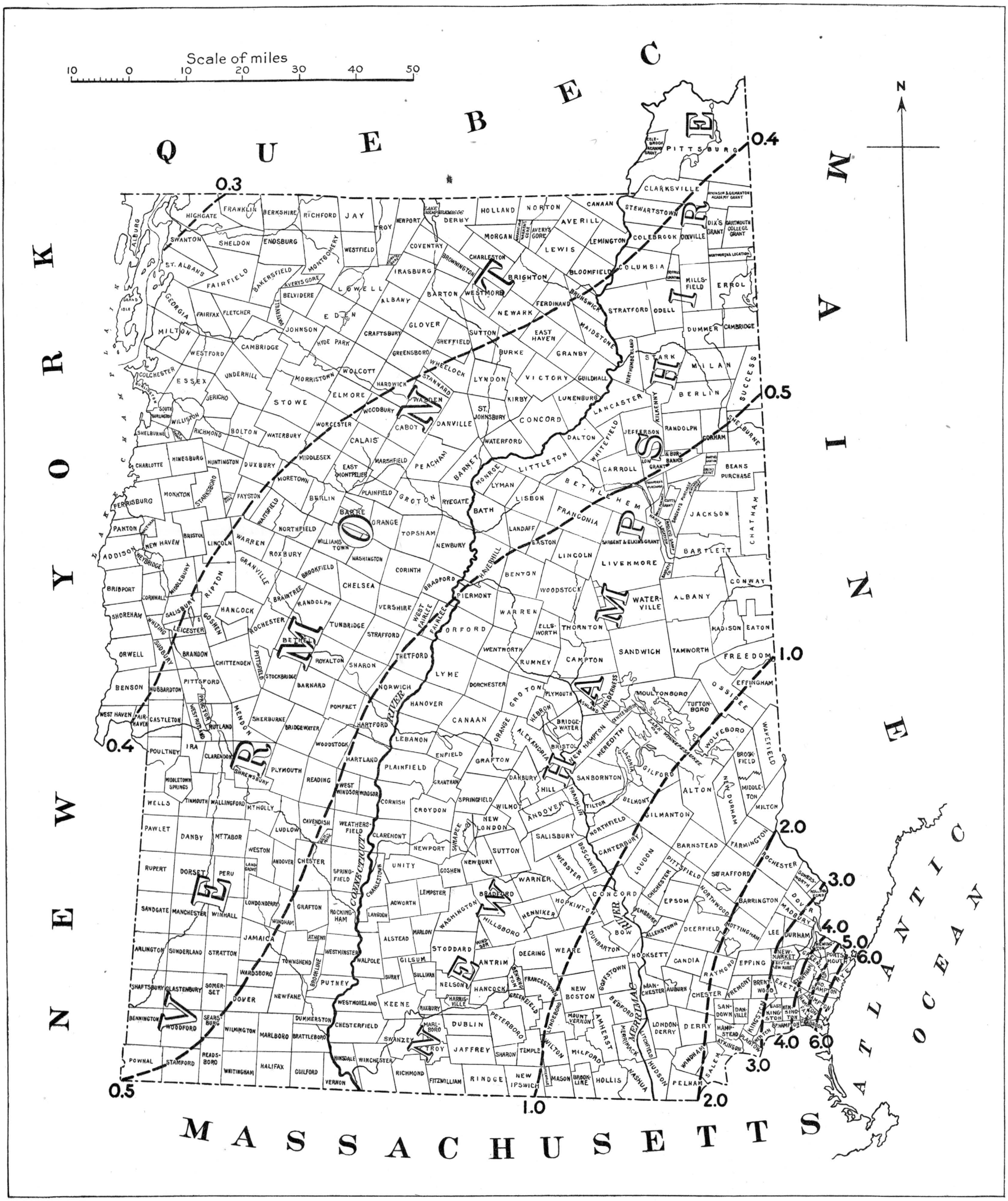
[Parts per million.]

Source.	Chlorine.	Source.	Chlorine.
Oxford County—Continued.		Waldo County—Continued.	
Fryeburg, well	1.0	Unity, reservoir	1.5
Gilead, reservoir	.6	Winterport, well	2.0
Middle dam, Richardson Lake	.6	Washington County:	
Upper dam, spring	.5	Baring, Spragues Falls	2.3
Welchville, well	1.0	Calais, spring	4.0
West Bethel, spring	.8	Cherryfield, spring	4.0
Penobscot County:		Eastport, Chadburn dam	2.4
Bangor, spring	1.5	Perry dam	3.2
Dexter, well	.7	water supply	3.1
Hampden, well	2.0	East Machias, lake	4.0
Old Town, spring	1.0	Edmonds, spring	4.0
Piscataquis County:		Harrington, spring	6.0
Greenville, spring	.5	Machias, spring	6.0
Guilford, spring	.5	York County:	
Sagadahoc County:		Alfred, well	2.5
Bath, lake	4.0	Cape Elizabeth, well	9.0
spring	6.0	Cornish, spring	1.5
water supply	4.0	Eliot, spring	4.0
Bowdoinham, spring	4.0	Hollis, well	3.0
Richmond, water supply	2.5	Kennebunk, spring	5.0
Somerset County:		well	6.0
Pittsfield, spring	1.0	Lebanon, well	4.0
The Forks, spring	.4	Limington, spring	2.0
Waldo County:		Lyman, spring	3.0
Brooks, well	3.0	Old Orchard, spring	6.0
Stockton Springs	6.0	Sandford, spring	2.7
Swanville, well	5.0	well	3.0
		South Berwick, spring	3.5
		Springfield, well	4.0

THE ISOCHLORS OF NEW HAMPSHIRE.

The New Hampshire isochlors (Pl. III) were drawn from observations obtained by Mr. H. E. Barnard, chemist, New Hampshire State board of health, and from the work of Mr. M. O. Leighton and the author.

The outlines follow the seacoast in a general way, but the inland lines (0.4 and 0.5 part per million) are deflected to some extent toward the coast by the influence of the White Mountains. The following is



NORMAL DISTRIBUTION OF CHLORINE, IN PARTS PER MILLION, IN NATURAL WATERS OF VERMONT AND NEW HAMPSHIRE.

an extract from Mr. Barnard's letter on the normal chlorine of New Hampshire:

I am inclosing the results of the chlorine determination of 570 waters, collected from 145 different towns. About 200 of these determinations, representing waters from the southeastern part of the State, near the coast, were made on samples collected expressly for the chlorine work and are from supplies of known purity. The remainder of the examinations were made in the course of our regular work on sanitary water analyses, and the results are selected from over 1,800 analyses. We feel confident that they represent normal chlorines, as they are mainly spring supplies. The chlorine factor was not accepted as normal, however, until complete sanitary analyses had proved the supply to be entirely free from contamination.

Some few results represent town supplies, and others are obtained from analyses of small mountain streams. The incorporation of the results of analyses of river water has been avoided because the chlorine content of an unpolluted river water is frequently less than that of the town through which it flows, due, of course, to the fact that the river is fed by streams and ponds along the mountains where the normal chlorine is low.

The chlorine content of waters along the coast has been determined carefully and is found to diminish so rapidly that 5 miles will frequently change the isochlor 10 parts per million. This is, of course, true only near the coast. It may be argued that determinations of chlorine in water located directly on the coast have little significance because of the liability of change of chlorine content when heavy storms sweep in off the sea. I have found that duplicate analyses, made at different seasons, showed differences so slight that they were well within the limit of error. Referring to the chlorine map you have drafted, I am surprised that our isochlors agree so closely.

The following list gives the observations which have had a bearing upon the determination of normal chlorine lines in the State of New Hampshire:

Chlorine determinations for New Hampshire.

[Parts per million.]

Source.	Samples.	Chlorine.	Source.	Samples.	Chlorine.
Belknap County:			Carroll Co.—Cont'd.		
Belmont	5	0.73	Lower Bartlett		0.5
Center Harbor	1	.9	Moultonboro		.9
Gilmantown	1	.75	Mount Pleasant	2	.66
Laconia	4	1.18	Ossipee	2	.87
Meredith	1	1.0	Snowville	2	.87
New Hampton	8	.79	Tamworth	2	1.0
Tilton	9	1.0	Wakefield	1	2.5
Carroll County:			Wolfboro	3	.73
Bartlett	1	.75	Cheshire County:		
Do		.7	Chesham	3	.72
Conway	3	.58	Dublin	5	.93
Eaton	1	.75	Fitzwilliam	1	1.0
Freedom	1	.75	Do		.7
Intervale	1	.5	Harrisville	3	.75

Chlorine determinations for New Hampshire—Continued.

[Parts per million.]

Source.	Samples.	Chlorine.	Source.	Samples.	Chlorine.
Cheshire Co.—Cont'd.			Grafton Co.—Cont'd.		
Jaffrey	....	0.8	Lincoln	3	0.46
Jaffrey, East	4	.87	Lisbon	4	.75
Keene	7	.85	Littleton	15	.74
Do	....	.7	Lyme	3	.78
Marlboro	2	.88	Orford	....	.5
Marlow	1	.5	Do	3	.82
Monadnock	1	1.0	Piermont	3	.67
Nelson	3	1.01	Pike	1	.49
Troy	1	1.0	Plymouth	....	.7
Walpole	2	.62	Do	10	.89
Winchester	1	.92	Warren	7	.77
Coos County:			Woodsville	3	.63
Berlin	3	.75	Hillsboro County:		
Colebrook	1	.5	Amherst	2	1.0
Dummer	....	.4	Antrim	7	1.01
Errolf	....	.3	Do	....	.9
Gorham	2	.75	Bennington	3	.67
Groveton	....	.5	Brookline	3	.14
Jefferson	1	.39	Deering	1	.60
Lancaster	2	.5	Francestown	2	1.0
Stratford	2	.5	Goffstown	6	1.5
Whitefield	3	.43	Greenfield	8	.79
Grafton County:			Greenville	....	1.2
Alexandria	1	.60	Hillsboro	2	.65
Ashland	....	.7	Hudson	6	1.34
Bethlehem	7	.55	Manchester	16	1.34
Do	....	.6	Mason	1	1.0
Bridgewater	1	.75	Mount Vernon	3	1.08
Bristol	4	.77	Nashua	3	1.5
Do	....	.6	New Ipswich	5	1.1
Campton	11	.65	Peterboro	23	.97
Do	....	.6	Weare	5	1.23
Canaan	12	.64	Wilton	6	1.13
Do	....	.7	Merrimack County:		
Franconia	1	.5	Allenstown	....	1.5
Grafton	2	.74	Andover	2	.82
Hanover	8	.78	Boscawen	3	.88
Do	....	.5	Bradford	4	.89
Haverhill	4	.6	Chichester	1	1.0

Chlorine determinations for New Hampshire—Continued.

[Parts per million.]

Source.	Samples.	Chlorine.	Source.	Samples.	Chlorine
Merrimack Co.—Con.			Rockingham County —Continued.		
Concord	21	1.28	Sandown	2	1.5
Do	....	1.1	Seabrook	3	9.20
Danbury	2	.95	South Hampton	6	4.3
Epsom	14	2.06	Stratham	2	6.7
Franklin	16	1.03			
Henniker	2	.73	Strafford County:		
Hill	2	1.0	Barrington	5	2.30
Hopkinton	3	1.03	Dover	13	3.19
Loudon	1	.93	Durham	1	3.75
Pembroke	2	1.5	Farmington	1	2.00
Penacook	1	1.1	Gonic	2	1.68
Pittsfield	3	1.5	Millton	1	1.75
Salisbury	3	1.0	Rochester	3	2.5
Suncook	2	1.5	Do	....	1.5
Sutton	5	.85	Salmon Falls	2	2.83
Warner	12	.89	Summersworth	6	2.65
Rockingham County:			Sullivan County:		
Atkinson	5	3.2	Charlestown	3	.87
Auburn	5	1.6	Claremont	9	.82
Exeter	....	3.7	Do	....	.7
Do	2	3.25	Cornish	3	.90
Hampton	....	6.0	Goshen	1	.6
Hampstead	6	2.59	Meriden	1	.65
Londonderry	5	1.75	Newport	3	.83
Newmarket	4	3.2	Plainfield	....	.6
Newton	6	3.60	Springfield	1	1.0
Portsmouth	6	4.0	Sunapee	11	.74
Salem	....	2.1	Unity	1	.6
Salem Depot	8	2.45	Washington	3	.6

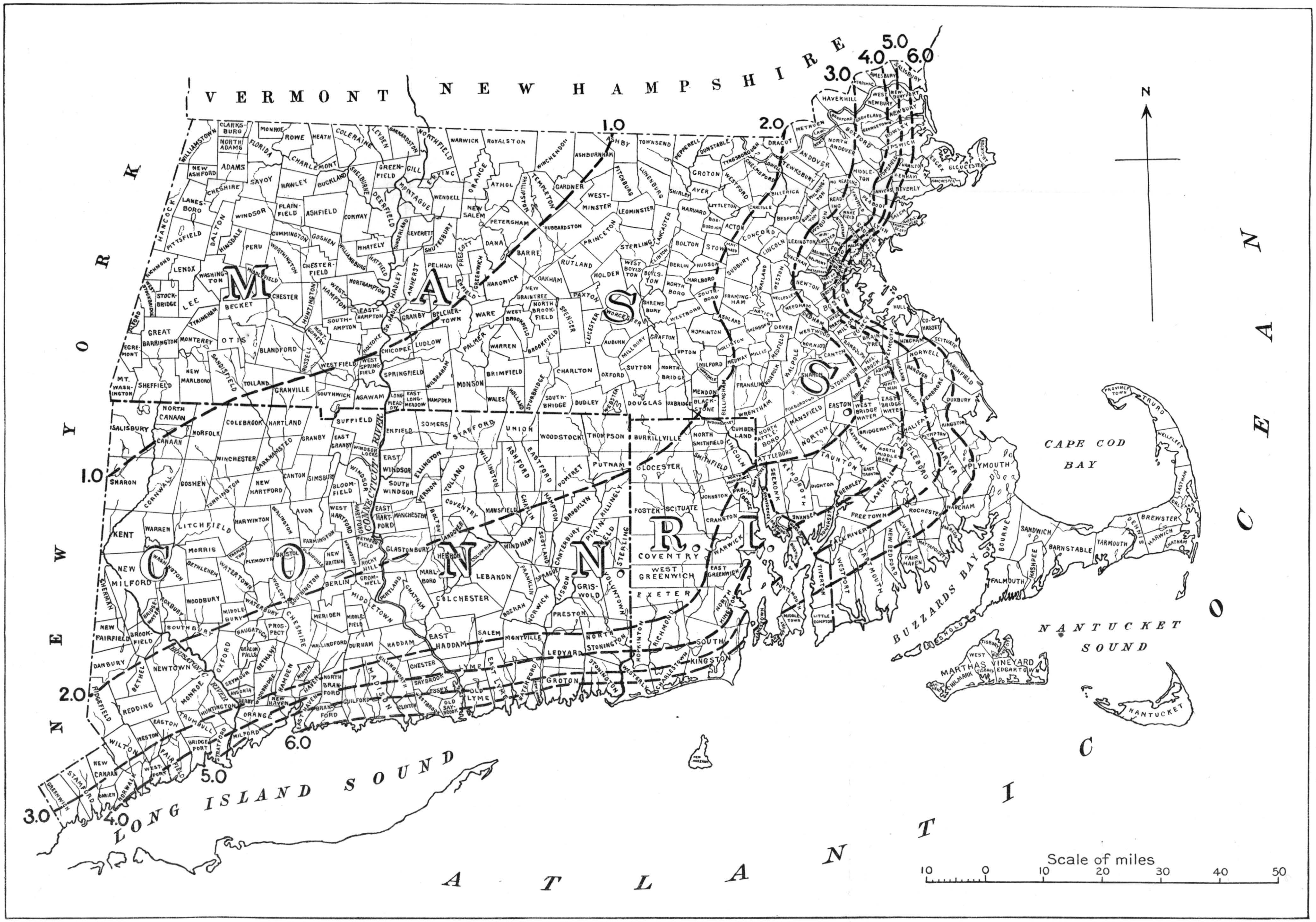
THE ISOCHLORS OF VERMONT.

The Vermont isochlors (Pl. III) are drawn from data obtained from Mr. C. P. Moat, chemist, Vermont State board of health. It will be seen that the isochlors are modified to a considerable extent by the Green Mountains, as well as by the White Mountains in New Hampshire. The following figures, supplied by Mr. Moat, are not only interesting as determinations of normal waters but also as showing the range of variation in these waters;

Chlorine determinations for Vermont.

[Parts per million.]

Source.	Samples.	Chlorine.	Source.	Samples.	Chlorine.
Addison County:			Lamoille County:		
Bristol	12	0.47	Cambridge	6	0.47
Lincoln	1	.3	Elmore	2	.45
Monkton	2	.6	Hyde Park	3	.57
Middlebury	7	.5	Johnson	5	.38
Shoreham	1	.3	Morrisville	2	.6
Vergennes	2	.5	Orange County:		
Whiting	2	.45	Bradford	4	.6
Bennington County:			Corinth	2	.6
Arlington	6	.5	Newbury	2	.65
Bennington	7	.5	Randolph	5	.56
Dorset	3	.5	Strafford	2	.45
Manchester	11	.5	Rutland County:		
Readsboro	6	.52	Mount Tabor	1	.5
South Shaftsbury	3	.5	Pittsford	5	.42
Stamford	1	.6	Poultney	4	.42
Caledonia County:			Proctor	6	.55
Barnet	1	.5	Rutland	7	.47
Hardwick	3	.57	Rutland Center	4	.45
Lyndonville	7	.44	Sudbury	1	.4
Lyndon	2	.5	Wallingford	1	.5
St. Johnsbury	4	.53	Washington County:		
West Burke	3	.33	Barre	4	.5
Chittenden County:			Berlin	2	.4
Charlotte	1	.5	Cabot	1	.4
Essex Junction	2	.6	Duxbury	2	.6
Jericho	1	.4	Marshfield	2	.45
South Burlington	1	.5	Middlesex	4	.4
Winooski	1	.6	Montpelier	9	.51
Essex County:			Northfield	9	.49
Brighton	4	.4	Waterbury	6	.53
Canaan	5	.52	Windham County:		
Island Pond	1	.3	Bellows Falls	1	.6
Franklin County:			Brattleboro	1	.6
Enosburg	1	.6	Saxtons River	2	.55
Fairfield	1	.6	Stratton	1	.6
Fairfax	1	.3	Townsend	1	.6
Montgomery	2	.55	Wilmington	3	.43
Richford	4	.6	Windsor County:		
St. Albans	2	.55	Barnard	4	.5
Swanton	5	.52	Bethel	1	.4



NORMAL DISTRIBUTION OF CHLORINE, IN PARTS PER MILLION, IN NATURAL WATERS OF MASSACHUSETTS, RHODE ISLAND, AND CONNECTICUT.

Chlorine determinations for Vermont—Continued.

[Parts per million.]

Source.	Samples.	Chlorine.	Source.	Samples.	Chlorine.
Windsor Co.—Cont'd.			Windsor Co.—Cont'd.		
Chester	4	0.55	Rochester	4	0.4
Hartford	5	.56	Royalton	2	.4
Norwich	7	.47	Springfield	9	.52
Pomfret	1	.7	Windsor	4	.5
Plymouth	1	.6	Woodstock	5	.4

Besides these observations the following may also be considered in estimating the isochlors for this State:

Chlorine determinations for Vermont—Additional list.

[Parts per million.]

Source.	Chlorine.	Source.	Chlorine.
Arlington, spring	0.5	Manchester, water supply	0.4
Barnet, water supply	.5	Middlesex, spring	.4
Bennington, spring	.4	Monkton, water supply	.5
Cambridge, spring	.4	Morrisville, spring	.5
East Burke, spring	.5	North Troy, spring	.5
Enosburg Falls, spring	.4	Readsboro, water supply	.5
Georgeville, spring just above State line	.4	St. Johnsbury, Stiles Pond	.5
Lincoln, spring	.5	Waltham, spring	.4

THE ISOCHLORS OF MASSACHUSETTS.

The Massachusetts isochlors (Pl. IV) are practically the same as those published by the Massachusetts State board of health in their report of 1890. In minor respects these lines have been modified to conform with the work in adjoining States. It is only in the isochlor of 1 part per million that any material change has been made. This line was modified to agree with the work in Connecticut and New York.

The northeast winds sweeping across this State have a tendency to drive the chlorine far inland, and it will be seen that most of the lines are farther from the coast than would be expected, and that this effect is greatest in the most exposed areas. In the western part of the State this is, to some extent, counteracted by the Holyoke Range and the Berkshire Hills.

The following average observations have influenced the establishment of the position of the Massachusetts isochlors:

Chlorine determinations for Massachusetts.

[Parts per million.]

Source.	Chlorine.
Berkshire County:	
Cheshire, reservoir	0.6
Dalton, Egypt Brook	.7
lower reservoir	.7
Great Barrington, Green River	.9
Hinsdale, east branch Housatonic River	.8
storage reservoir	.7
Lee, lower reservoir	.7
Lenox, reservoir	.7
North Adams, Notch Lake	.6
Pittsfield, Pontoosuc Lake	.4
Millbrook reservoir	.9
Sackett Brook	.8
Sheffield, spring	.7
Stockbridge, Lake Averie	.7
Williamstown, Cold Spring	.6
Sherman Spring	.5
Bristol County:	
Fall River, Watuppa Lake	5.2
New Bedford, Acushnet reservoir	5.3
Essex County:	
Andover, spring	2.4
Danvers, Middleton Pond	3.5
Haverhill, Crystal Lake	2.7
Ipswich, storage reservoir	5.3
Methuen, spring	2.0
Franklin County:	
Conway, brook	.7
Deerfield, brook	.6
Greenfield, Glen Brook	1.1
Montague, Lake Pleasant	1.0
Northfield, reservoir	.7
Orange, reservoir	.9
Whateley, West Brook	.9
Hampden County:	
Chester, Austen Brook reservoir	.6
Chicopee, Cooley Brook reservoir	1.1
Granville, middle branch Westfield River	1.2
Ludlow, Chapin Pond	1.0
Hampden County—Continued.	
Monson, well	1.2
Russell, middle branch Westfield River	.7
Springfield, Ludlow reservoir	1.2
Hampshire County:	
Huntington, east branch Westfield River	1.0
middle branch Westfield River	.9
Middlesex County:	
Ashland, Basin No. 4	2.3
Concord, Sandy Pond	2.5
Framingham, reservoir	2.3
Hudson, Gates Pond	2.0
Pepperell, spring	1.5
Sudbury, reservoir	2.2
Wayland, Snake Brook	2.3
Nantucket County:	
Nantucket, Wannacomet Pond	22.6
Plymouth County:	
Hingham, Accord Pond	6.0
Lakeville, Long Pond	4.5
Plymouth, Little South Pond	6.2
Worcester County:	
Ashburnham, storage reservoir	1.3
Berlin, Fosgate Brook	1.9
Clinton, Lyndes Brook	1.6
Holden, Tatnuck Brook	1.2
Leicester, storage reservoir	1.2
Leominster, Haynes reservoir	1.2
North Brookfield, Doan Pond	1.2
Rutland, Musquahog Lake	1.4
Southbridge, reservoir	1.3
Spencer, Shaw Pond	1.4
Sterling, Stillwater River	1.6
Worcester, Bottomly Pond	1.5
Kent reservoir	1.5
Tatnuck Brook reservoir	1.3

THE ISOCHLORS OF RHODE ISLAND.

The lines of equal chlorine for Rhode Island (Pl. IV) are drawn from data furnished by Dr. Gardner T. Swarts, secretary of the Rhode Island State board of health. Observations made in Massachusetts and Connecticut were also of great assistance in defining these lines. The following analyses in Rhode Island have influenced the determination of their position:

Chlorine determinations for Rhode Island.

[Parts per million.]

Source.	Chlorine.	Source.	Chlorine.
Kent County:		Providence County—Continued.	
Washington, Carr's pond	2.9	Harrisville, Wallum Pond	1.8
East Greenwich	4.0	Foster, spring	2.1
Newport County:		Diamond Hill, well	2.9
Block Island, Sand's pond	30.8	Washington County:	
Providence County:		Wakefield, spring	5.4
Pawtuxet Valley, reservoir	3.4	Rocky Brook	5.8
Pawtucket supply, Abbott Run	3.2	West Kingston, Barber's pond	3.2
Woonsocket, reservoir No. 3	2.2	100-acre Pond	3.6

THE ISOCHLORS OF CONNECTICUT.

The normal chlorine lines in Connecticut (Pl. IV) were established by Dr. Herbert E. Smith, chemist, Connecticut State board of health, and Dr. Frederick S. Hollis, from whose article in the report of the Connecticut State board of health for 1902, together with their observations on normal waters of the State, the extract quoted below is taken.

Observations since obtained from Doctor Smith give data for adding the 4, 5, and 6 lines to the map. The strong protecting influence of Long Island cuts these lines off on the western coast in a very peculiar manner.

NORMAL DISTRIBUTION OF CHLORINE IN CONNECTICUT.

In the report of the Connecticut State board of health for 1895 a chlorine map of the State was published, which was based on averages of chlorine determinations from 38 sources. The origin of chlorine in natural waters and the value of an accurate knowledge of the normal chlorine of a district, any excess above which is an important factor in establishing the degree of contamination, were fully discussed.

During the seven years that have elapsed since the publication of the map many of the sources used in the construction of the isochlorine lines have been reexamined, and many new sources have been examined by making monthly or bimonthly analyses during one or more years. Much information has been gained also from the large number of analyses of individual samples from different parts of the State, as in the systematic examination of spring waters. The averages of the chlorine determinations from those sources which appear to be free or practically free from contamination are used in the construction of the new map. The 71 sources are divided, according to the number of analyses, into three groups and entered alphabetically. * * * Each average is entered on the map, and isochlorine lines are drawn indicating the center of the comparatively limited zones in which the chlorine agrees with that of the given chlorine line.

Considerable difficulty was found, as in the case of the earlier map, in locating the lines in the eastern part of the State, where there are very few public supplies and from which section but few determinations have been made. Samples were analyzed monthly from April to September, 1902, from Wyassup Pond, in North Stonington; Beachdale Pond, in Voluntown; Moosup Pond, in Plainfield (the drainage area of which extends into Killingly; the Danielson reservoirs, in Killingly, and Crystal Pond, between Eastford and Woodstock. These, with previously collected data, probably locate the lines with a fair degree of accuracy, and have resulted in lowering the 3 and 2.5 lines considerably and in raising the 2 and 1.5 lines, as compared with the earlier map.

AVERAGES OF CHLORINE DETERMINATIONS UPON WHICH THE MAP IS BASED.

[Parts per million.]

SOURCES FROM WHICH TWELVE OR MORE DETERMINATIONS HAVE BEEN MADE.

Ansonia	2.8	Kent	1.6	Ridgefield	2.2
Berlin	1.9	Killingly	2.3	Seymour	2.3
Bethany	2.4	Killingworth	2.9	Southington	1.7
Bethel	1.9	Manchester	1.8	Do	1.9
Branford	4.5	Meriden	1.9	South Manchester	1.8
Bridgeport	3.7	Middletown	2.5	Stamford	2.3
Bristol	1.5	Morris	1.6	Stonington	5.1
Chaplin	1.9	Naugatuck	2.0	Thomaston	1.6
Danbury	2.3	Naugatuck River	1.6	Watertown	1.7
Durham	2.7	New Canaan	2.7	Waterford	3.3
East Haven	4.1	New Milford	1.8	West Hartford	1.5
Easton	2.9	North Canaan	1.2	West Haven	6.0
Farmington	1.8	Norwich	2.6	Winchester	1.3
Goshen	1.5	Orange	2.3	Wolcott	1.9
Greenwich	3.0	Rockville	1.6	Do	2.0
Hamden	2.4				

SOURCES FROM WHICH SIX DETERMINATIONS HAVE BEEN MADE.

Chester	3.0	Oxford	1.7	Union	1.4
Eastford	1.8	Do	2.2	Voluntown	2.7
Moosup	2.2	Stafford Springs	1.6	West Cornwall	1.1
North Stonington	3.1	Thomaston	1.6	Do	1.3

SOURCES FROM WHICH THREE DETERMINATIONS HAVE BEEN MADE.

East Granby	1.6	New Hartford	1.3	Southington	1.9
East Hartford	2.0	North Canaan	1.1	Simsbury	1.8
Farmington	1.9	Portland	2.4	Westbrook	6.7
Griswold	2.3	Plymouth	1.9	Windsor Locks	1.5
Hebron	2.6	Salisbury	0.9	Woodbury	1.9
New Canaan	2.7	Shelton	3.1		

Chlorine determinations for Connecticut.

[Parts per million.]

Source.	Number of samples.	Average.	Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Ansonia [a]	12	2.8	1897	3.40	3.25	2.80	2.75	2.64	2.45	3.20	2.30	2.30	2.65	3.00	2.90
Berlin, Kenmere reservoir (Meriden supply)	12	1.9	1899	1.70	2.40	1.90	1.30	1.70	1.60	1.90	1.70	2.00	1.60	2.40	2.30
Bethany, Dawson reservoir system [b]	40	2.4	1894	2.95	3.32	3.06	2.98	2.78	2.34	2.24	2.36	2.76	2.85	3.07	2.95
			1897	.....	.....	.....	.....	.....	.....	.....	.....	2.40	.....	.....	3.10
			1898	.....	.....	1.80	.....	.....	1.90	.....	.....	1.90	.....	.....	1.90
			1899	.....	.....	1.60	.....	.....	1.80	.....	.....	1.80	.....	.....	2.90
			1900	.....	.....	2.40	.....	.....	2.00	.....	.....	1.86	.....	.....	2.60
			1901	2.76	2.70	2.30	2.00	2.06	1.80	1.80	1.46	2.02	2.60	2.50	2.44
			1902	2.50	2.60	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Bethel, storage res.	12	1.9	1897	2.50	2.40	1.90	1.80	1.80	1.80	1.90	1.70	1.60	1.80	2.25	2.35
Branford	12	4.5	1900	4.60	4.00	3.50	6.30	4.40	4.50	3.90	4.62	4.10	4.34	4.70	4.96
Bridgeport (Island Brook supply)	12	3.7	1896	3.90	3.50	3.70	3.70	3.50	3.15	3.20	3.70	3.90	3.50	4.20	4.70
Bristol, storage res. and Poland River	24	1.5	1895	1.9	1.9	1.8	1.2	1.4	1.5	1.3	1.4	1.3	1.6	1.7	1.4
			1901	2.06	1.60	1.76	1.50	1.10	1.06	1.14	1.34	1.00	1.50	1.60	1.70
Chaplin, Natchaug River (Willimantic supply)	35	1.9	1889	.....	.....	.....	.....	.....	.....	.....	1.8	2.3	2.5	2.3	1.8
			1890	1.8	2.1	1.8	1.5	1.6	1.4	1.8	2.1	2.0	2.3	1.8	2.4
			1891	2.0	1.5	1.3	1.8	1.7	1.3	.....	.....	.....	.....	.....	.....
			1899	1.6	2.10	1.10	1.60	1.70	1.20	1.60	1.90	2.10	2.70	3.70	2.70
Chester, Watrous Pond [c]	6	3.0	1895	.....	.....	.....	2.9	2.8	2.9	2.8	3.1	.....	3.7	.....	.....
Danbury (Kohanza supply)	12	2.5	1896	.....	2.20	.....	3.20	.....	2.25	.....	3.30	.....	2.20	.....	2.20
			1900	3.10	.....	1.70	.....	1.80	.....	2.30	.....	2.26	.....	3.46	.....
East Lake and Padanaram reservoir	12	2.1	1896	.....	2.20	.....	2.25	.....	3.30	.....	2.50	.....	1.90	.....	1.90
			1900	2.60	.....	1.90	.....	1.90	.....	1.90	.....	1.38	.....	2.06	.....
Durham, Lake Pistepaug [d]	12	2.6	1895	3.4	2.7	2.9	2.7	2.5	2.[illegible]	2.5	2.4	2.5	2.8	2.6	2.5
Eastford, Crystal Pond [e]	6	1.8	1902	.....	.....	.....	1.94	1.84	1.74	1.60	1.80	.....	1.66	.....	.....
East Granby [f]	5	1.6	1898	.....	.....	.....	.....	1.6	1.6	1.4	.....	{1.5 1.7}	.....	.....	.....
East Hartford	3	2.0	1897	.....	1.90	.....	.....	.....	2.00	.....	.....	.....	.....	2.20	.....
East Haven, Lake Saltonstall (New Haven supply)	36	4.1	1890	.....	.....	.....	.....	.....	.....	.....	3.6	3.7	4.1	3.9	3.7
			1891	3.6	3.5	3.5	3.8	.....	3.7	.....	.....	.....	.....	.....	.....
			1895	.....	.....	.....	3.8	4.0	4.0	4.2	4.2	4.3	.....	.....	.....
			1897	.....	.....	.....	.....	.....	.....	.....	.....	4.10	.....	.....	4.10
			1898	.....	.....	4.40	.....	.....	4.50	.....	.....	4.20	.....	.....	4.10
			1899	.....	.....	4.00	.....	.....	4.30	.....	.....	4.20	.....	.....	4.30
			1900	.....	.....	3.90	.....	.....	4.20	.....	.....	4.80	.....	.....	4.70
			1901	.....	.....	4.74	.....	.....	4.46	.....	.....	4.66	.....	.....	4.20
			1902	4.30	4.20	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

[a] Ansonia Water Company. From storage reservoir on Beaver Brook.
[b] New Haven supply. Dawson reservoir is in Woodbridge on West River, and receives water from Chamberlain reservoir on Sargent River and from Bethany reservoir, 4 miles above Dawson reservoir on West River.
[c] Situated partly in Woodstock. Samples by Dr. F. S. Smith from the source, which is a small natural lake.
[d] Wallingford public supply.
[e] Samples by Dr. H. H. Converse, of Eastford.
[f] Samples by Dr. C. M. Wooster, of Tariffville, from a small private reservoir or lake in East Granby.

Chlorine determinations for Connecticut—Continued.

[Parts per million.]

Source.	Number of samples.	Average.	Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Easton, Mill River (Bridgeport supply)	12	2.9	1896	3.05	2.40	2.20	2.85	2.70	2.60	2.60	2.90	3.00	2.80	3.45	3.55
Farmington	3	1.9	1897	.....	2.70	.....	.....	.....	.....	1.60	.....	.....	1.25	.....	.....
Hartford, reservoir No. 4	12	1.8	1898	1.84	1.60	1.60	1.90	1.80	1.80	1.70	1.70	1.80	1.60	1.90	2.30
Goshen (Torrington supply)	12	1.5	1897	1.60	1.70	1.15	1.40	1.50	1.30	1.70	1.10	1.40	1.50	2.10	2.00
Greenwich, Rockwoods Pond and Putnam Lake	36	3.0	1896	3.84	3.42	3.20	3.30	3.60	3.75	3.40	3.40	3.80	3.20	3.40	3.40
			1898	3.50	3.00	2.60	2.60	2.90	2.30	2.70	2.20	2.40	2.80	3.10	3.00
			1901	3.34	3.70	3.50	2.94	2.60	2.26	2.58	2.74	2.30	2.00	2.72	2.10
Griswold (Jewett City supply)	3	2.6	1898	3.30	.....	.....	.....	.....	2.50	.....	.....	.....	2.10	.....	.....
Hamden, Lake Wintergreen (New Haven supply)	38	2.4	1889	.....	.....	.....	.....	.....	.....	.....	2.0	2.0	2.8	3.3	2.6
			1890	3.0	3.0	3.3	2.5	2.5	2.8	2.8	.....	.....	.....	.....	.....
			1895	.....	.....	.....	2.2	2.4	2.4	2.6	2.6	2.5	.....	.....	.....
			1897	.....	.....	.....	.....	.....	.....	.....	.....	2.45	.....	.....	3.00
			1898	.....	.....	2.00	.....	.....	1.90	.....	.....	1.80	.....	.....	1.90
			1899	.....	.....	1.70	.....	.....	1.90	.....	.....	1.60	.....	.....	2.30
			1900	.....	.....	1.90	.....	.....	2.70	.....	.....	2.80	.....	.....	3.00
			1901	.....	.....	3.18	.....	.....	2.00	.....	.....	2.20	.....	.....	2.20
			1902	2.20	2.40	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Hebron Spring[a]	5	2.3	1895	.....	.....	.....	.....	2.6	2.2	2.2	2.3	2.2	.....	.....	.....
Kent, reservoir	17	1.6	1894	1.7	1.4	1.4	1.5	1.5	1.4	1.2	1.4	2.2	.....	2.1	1.9
			1900	1.90	.....	1.20	.....	1.50	.....	1.90	.....	1.04	.....	1.86	.....
Killingly[b]	12	2.3	1896	.....	2.00 1.80 2.20	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
			1897	2.70	2.70	2.70	.....	.....	.....	.....	.....	.....	.....	.....	.....
			1902	.....	.....	.....	2.26	2.30	2.00	2.10	2.30	2.40	.....	.....	.....
Killingworth (Clinton supply)	12	2.9	1901	3.80	3.70	3.44	2.30	2.74	2.14	2.56	3.10	2.20	3.40	2.94	3.00
Manchester:															
Storage reservoir	6	1.7 (both)	1900	1.80	.....	1.30	.....	1.60	.....	1.80	.....	1.18	.....	1.46	.....
Distributing reservoir	6		1900	1.70	.....	1.70	.....	1.80	.....	2.10	.....	1.90	.....	1.74	.....
Meriden, Merimere reservoir	35	1.9	1889	.....	.....	.....	.....	.....	.....	.....	1.5	2.0	2.0	1.8	2.0
			1890	1.8	2.0	2.4	1.9	2.3	1.8	2.0	1.8	2.1	1.9	1.8	2.0
			1891	2.1	2.1	1.9	1.5	2.4	2.1	.....	.....	.....	.....	.....	.....
			1899	1.70	1.70	1.40	1.50	1.40	1.10	1.30	1.60	1.70	1.80	1.80	1.80
Middletown, Laurel Brook reservoir	35	2.5	1889	.....	.....	.....	.....	.....	.....	.....	2.0	2.3	2.3	2.5	2.5
			1890	2.3	2.8	2.8	2.3	3.0	2.3	2.4	2.3	2.3	2.3	2.5	2.5
			1891	2.0	2.1	2.3	2.3	2.5	1.8	.....	.....	.....	.....	.....	.....
			1899	2.40	3.00	2.10	2.10	2.40	1.70	2.40	2.90	2.90	3.30	2.80	3.10
Moosup, Moosup Lake[c]	4	2.2	1902	.....	.....	.....	.....	2.50	.....	2.16	.....	2.10	2.10	.....	.....
Morris[d]	12	1.6	1901	1.78	1.60	1.50	1.70	1.56	0.96	1.46	1.58	1.90	1.50	1.90	1.42

[a] Samples by Dr. C. H. Pendleton from a natural spring in the eastern part of Hebron.
[b] Samples in 1896 collected February 26 by Mr. A. B. Prentice from the various reservoirs of the Danielson supply. Months of 1897 sample collections not given. Samples in 1902 by Mr. G. S. Brown from a tap in Danielson.
[c] Samples by Dr. W. W. Adams, of Moosup. Drainage area partly in Killingly.
[d] Branch of Naugatuck River (Waterbury supply).

Chlorine determinations for Connecticut—Continued.

[Parts per million.]

Source.	Number of samples.	Average.	Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Naugatuck, storage reservoir	24	2.0	1895	2.2	2.2	2.0	1.5	2.1	1.9	1.7	1.8	2.0	2.3	2.7	2.2
			1901	2.52	3.10	1.60	1.66	1.40	1.30	1.86	1.66	1.76	2.10	2.00	2.14
Naugatuck River, above Torrington	50	1.6	1893	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.8	1.4
			1894	1.4	1.7	1.3	1.2	1.3	0.9	1.5	1.4	2.0	2.0	1.6	1.5
			1895	1.7	1.6	1.8	1.6	1.5	1.6	1.3	1.6	1.7	2.0	2.3	2.1
			1896	1.80	1.65	1.40	1.30	1.65	1.55	2.20	1.90	2.30	1.65	1.50	1.80
			1897	1.30	1.40	1.30	1.20	1.30	1.20	1.40	1.10	1.40	1.50	2.00	1.80
New Canaan	3	2.7	1897	.....	3.40	.....	.....	.....	.....	2.00	.....	.....	2.70	.....	.....
Norwalk, storage reservoir	35	2.7	1894	3.5	3.0	2.6	2.6	2.4	1.8	2.2	2.2	2.4	2.9	3.3	3.3
			1897	3.45	3.40	2.90	3.00	2.70	2.80	3.00	2.50	2.50	2.60	2.90	2.70
			1900	3.00	2.20	2.70	2.40	2.20	1.90	2.00	2.50	2.46	2.74	.....	3.06
New Hartford:															
South reservoir	3	1.3 (both)	1898 (both)	.....	1.20	.....	.....	.....	1.10	.....	.....	.....	1.70	.....	.....
Stone Brook reservoir	3		.....	.....	1.50	.....	.....	.....	1.30	.....	.....	.....	1.00	.....	.....
New Milford	12	1.8	1897	2.00	2.30	1.70	1.70	1.70	1.20	1.30	1.60	1.80	2.10	a3.60	2.90
North Canaan:															
Norfolk supply	3	1.1	1897	.....	1.10	.....	.....	.....	.....	1.10	.....	.....	1.05	.....	.....
Public supply	18	1.2	1894	1.5	0.9	1.2	1.0	1.4	1.2	1.0	1.1	1.3	1.3	1.4	1.6
			1900	1.20	.....	1.00	.....	1.60	.....	1.30	.....	1.00	.....	1.40	.....
North Stonington, Wyassup Pond b	6	3.1	1902	.....	.....	.....	3.24	2.74	3.40	2.70	3.40	3.20	.....	.....	.....
Norwich, storage res.	47	2.6	1889	.....	.....	.....	.....	.....	.....	.....	2.3	2.0	2.3	1.5	2.5
			1890	2.0	2.5	2.5	2.8	2.1	2.3	3.1	2.4	2.5	2.7	2.9	3.4
			1891	2.8	2.6	2.3	2.7	2.5	2.6	.....	.....	.....	.....	.....	.....
			1894	3.2	2.4	3.3	2.9	3.2	2.9	3.1	3.3	3.5	2.5	3.2	3.6
			1899	2.20	2.50	2.20	2.30	1.60	2.00	2.20	2.60	2.10	2.10	3.20	2.40
Orange, Maltby Lake, (New Haven supply)	20	2.3	1897	.....	.....	.....	.....	.....	.....	.....	.....	2.50	.....	.....	2.90
			1898	.....	.....	1.90	.....	.....	2.30	.....	.....	2.00	.....	.....	2.50
			1899	.....	.....	1.30	.....	.....	1.50	.....	.....	1.60	.....	.....	1.90
			1900	.....	.....	2.10	.....	.....	2.70	.....	.....	3.00	.....	.....	3.06
			1901	.....	.....	1.78	.....	.....	2.44	.....	.....	2.30	.....	.....	2.56
			1902	2.58	2.66	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Oxford:															
Hatter's Spring c	6	1.7	1895	.....	.....	.....	1.8	1.8	1.5	1.7	1.7	1.9	.....	.....	.....
Towantic Spring d	5	2.2	1895	.....	.....	.....	2.2	2.5	2.0	2.1	2.0	.....	.....	.....	.....
Plainville	3	1.9	1897	.....	2.20	.....	.....	.....	.....	1.90	.....	.....	1.70	.....	.....
Plymouth (Terryville supply)	3	1.9	1897	.....	.....	2.30	.....	.....	.....	1.60	.....	.....	.....	1.70	.....
Portland	3	2.4	1897	.....	2.30	.....	.....	.....	.....	2.30	.....	.....	2.50	.....	.....
Ridgefield	12	2.24	1901	2.74	2.70	2.20	2.10	2.50	1.50	1.80	2.30	2.00	2.14	2.26	2.64
Rockville, Schenipsit Lake	23	1.6	1890	.....	.....	.....	.....	.....	.....	.....	1.7	1.5	1.5	1.8	2.6
			1891	1.8	1.1	1.3	1.8	1.5	1.8	.....	.....	.....	.....	.....	.....
			1900	1.20	1.70	1.30	1.50	1.30	1.30	1.50	1.40	1.50	1.30	1.60	1.46
Salisbury (Lakeville supply)	3	0.9	1898	.....	.80	.....	.....	.....	.70	.....	.....	.....	1.30	.....	.....

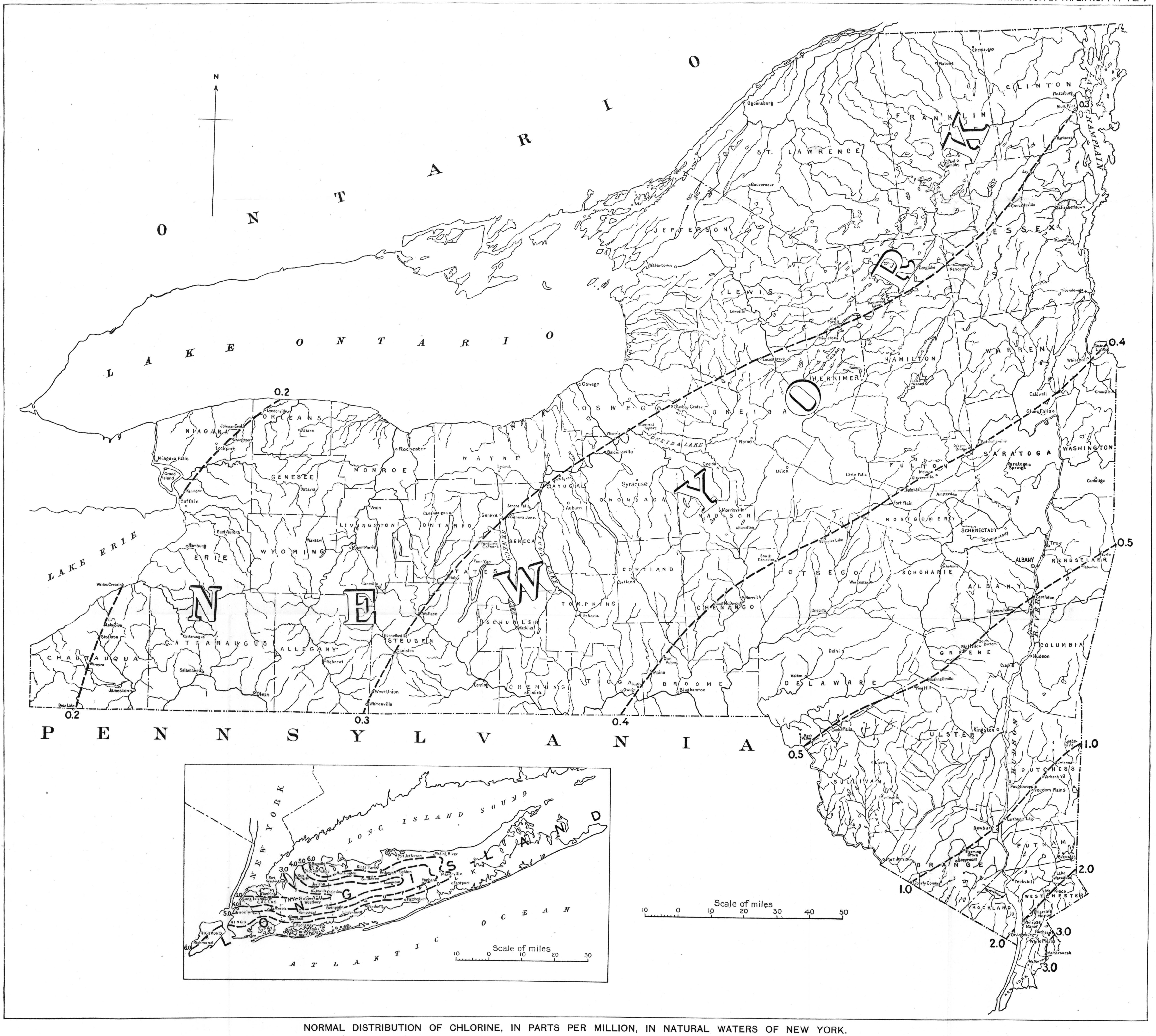
a Not included in average.
b Samples by Mr. E. H. Knowles, of North Stonington.
c Samples by Dr. Lewis Barnes from a natural spring located on the west side of Little River Valley, in Oxford.
d Samples by Dr. Lewis Barnes from a natural spring located about half a mile east of Hatter's Spring.

Chlorine determinations for Connecticut—Continued.

[Parts per million.]

Source.	Number of samples.	Average.	Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
Seymour, Fountain Water Co. (Ansonia supply)	12	2.3	1898	2.70	2.60	2.20	2.30	2.20	2.10	2.20	2.40	2.30	2.60	1.80	2.20
Shelton	3	3.1	1897	.....	2.90	.....	.....	.....	.....	3.30	.....	.....	3.00	.....	.....
Simsbury	3	1.8	1898	.....	.....	1.30	.....	.....	2.00	.....	.....	.....	2.10	.....	.....
Southington (New Britain supply):															
Roaring Brook	12	1.7	1899	1.50	1.40	0.70	1.60	1.60	1.80	2.00	2.20	1.70	2.00	2.10	2.20
Shuttle Meadow Lake	46	1.9	1889	.....	.....	.....	.....	.....	.....	.....	1.3	1.8	2.0	1.5	1.8
			1890	2.3	2.5	2.3	2.5	2.3	2.0	2.0	1.8	2.2	1.8	1.8	1.8
			1891	1.7	1.9	1.6	2.0	2.0	1.6	.....	.....	.....	.....	.....	.....
			1894	1.9	.....	1.9	2.0	2.1	2.0	2.0	2.0	2.9	2.3	2.1	1.8
			1899	1.50	1.20	1.40	1.50	1.90	2.70	2.30	1.70	1.90	2.00	2.10	2.10
South Manchester:															
Porter reservoir	24	1.8	1900	1.40	.....	1.50	.....	1.90	.....	1.80	.....	1.90	.....	2.30	.....
Taylor storage res.			1894	2.1	1.5	1.3	1.7	1.6	1.6	2.0	2.2	1.9	2.5	2.3	2.1
			1900	1.70	.....	1.50	.....	1.50	.....	1.70	.....	1.58	.....	.....	2.10
Stafford Springs[a]	6	1.6	1900	1.60	.....	1.40	.....	1.50	.....	1.50	.....	.94	.....	2.50	.....
Stamford, Trinity Lake, N. Y.	24	2.3	1889	.....	.....	.....	.....	.....	.....	.....	1.8	.....	2.8 2.3	2.6	1.8
			1890	2.5	2.4	2.3	2.3	2.3	1.8	2.0	.....	.....	.....	.....	.....
			1899	2.10	1.50	1.50	1.60	1.90	1.60	2.00	2.70	2.70	3.20	4.00	3.10
Stonington, storage reservoir	22	5.1	1894	.....	5.8 6.0	4.4	3.1	5.4	.....	5.2	5.5	.....	5.7	7.0	6.7
			1900	5.00	4.50	4.30	4.30	4.50	3.60	4.30	3.10	4.86	5.00	5.30	5.60
Thomaston:															
Storage reservoir	35	1.6	1889	.....	.....	.....	.....	.....	.....	.....	1.0	2.0	1.8	1.8	1.3
			1890	1.8	1.8	1.4	1.9	1.3	1.1	1.5	1.7	1.7	1.5	1.5	1.8
			1891	1.6	1.3	1.2	1.6	1.4	1.3	.....	.....	.....	.....	.....	.....
			1894	2.0	2.0	2.1	1.7	1.7	1.4	1.6	1.6	1.9	1.8	2.0	2.6
Spring[b]	12	1.6	1894	1.3	1.3	1.5	1.4	1.5	1.2	1.5	1.6	1.9	1.9	2.0	2.0
Union[c]	6	1.4	1895	.....	.....	.....	1.4	1.2	1.3	1.4	1.5	1.8	.....	.....	.....
Voluntown:															
Beachdale Pond[d]	9	2.7	1902	.....	.....	.....	2.36	2.54	2.18	2.62	2.90	2.80	.....	.....	.....
Beach Pond			1896	.....	3.3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Great Meadow Brook			1896	.....	3.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Mt. Misery Stream			1896	.....	2.7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Waterford, Lake Konomoc (New London supply)	24	3.3	1894	3.8	3.3	3.3	3.5	3.5	3.3	3.5	3.4	2.7	3.7	3.6	3.8
			1899	3.10	3.10	3.10	2.90	3.20	3.00	3.30	2.70	2.90	3.10	3.10	3.20
Watertown, Farm Brook (Waterbury supply)	35	1.7	1898	.....	1.60	1.20	1.20	1.60	1.50	1.90	1.10	1.60	2.70	1.40	1.40
			1899	1.20	1.70	1.30	1.20	1.40	.90	1.60	1.70	1.90	2.10	3.10	2.50
			1900	1.90	1.90	2.30	1.80	1.30	1.10	1.90	1.80	1.64	2.00	2.90	1.60
Westbrook[e]	5	6.7	1895	.....	.....	.....	.....	4.7	6.8	7.1	7.4	7.3	.....	.....	.....
West Cornwall:															
Lake[f]	6	1.1	1895	.....	.....	.....	.9	1.1	1.2	1.1	1.1	1.4	.....	.....	.....
Spring[g]	6	1.3	1895	.....	.....	.....	1.0	1.2	1.3	1.2	1.3	1.8	.....	.....	.....

[a] Roaring Brook; part of drainage area in Union.
[b] Samples by Dr. R. S. Goodwin from a natural spring located in the western part of Thomaston.
[c] Samples by Dr. F. L. Smith, of Stafford Springs, from a small natural lake located in the western part of Union and used as a private water supply.
[d] Samples by Rev. E. Dewhurst, of Voluntown.
[e] Samples by Dr. T. B. Bloomfield from Dies' Pond.
[f] Samples by Mr. T. S. Gold from a small natural lake.
[g] Samples by Mr. T. S. Gold from a natural spring which is used as a private supply.



NORMAL DISTRIBUTION OF CHLORINE, IN PARTS PER MILLION, IN NATURAL WATERS OF NEW YORK.

Chlorine determinations for Connecticut—Continued.

[Parts per million.]

Source.	Number of samples.	Average.	Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
West Hartford:															
Reservoir No. 1...	58	1.6	1898	1.70	1.64	1.20	1.70	1.60	1.50	1.90	1.40	.....	1.20	1.80	1.70
No. 2...			1898	1.50	1.50	1.30	1.70	1.60	1.50	1.60	1.10	1.20	1.10	1.50	1.40
No. 3...			1898	1.80	1.50	1.40	1.70	1.80	1.80	2.00	1.50	1.50	1.40	1.50	1.50
No. 5...			1898	1.60	1.70	1.40	1.70	1.60	1.50	1.90	1.30	1.40	1.20	.....	1.50
No. 6...			1898	1.24	1.30	.90	1.50	1.50	1.50	1.60	1.20	1.40	1.20	1.50	1.40
W. Haven, storage res.	12	6.0	1895	6.6	6.7	6.3	5.4	5.8	5.8	4.8	6.0	4.7	6.5	6.1	6.8
Winchester, Highland Lake and Mad River (Winsted supply)............	24	1.3	1895	1.9	1.9	1.9	1.4	1.4	1.5	1.4	1.4	1.4	1.5	1.3	1.4
			1901	1.56	1.30	1.36	1.22	1.24	1.10	1.12	.90	.94	.94	.90	1.16
Windsor Locks	3	1.5	1897	.....	1.65	.....	.....	.....	.....	1.50	.....	.....	1.45	.....	.....
Wolcott, storage res. (Southington supply)	12	1.9	1894	2.5	2.1	2.0	2.0	1.8	1.5	1.4	1.6	1.7	2.0	2.4	2.3
East Mountain storage res. (Waterbury supply).	23	2.0	1889	.....	.....	.....	.....	.....	.....	.....	1.9	1.8	2.0	1.9	2.0
			1890	2.3	1.5	1.9	2.8	2.3	2.1	2.6	2.3	2.0	1.9	2.0	1.9
			1891	1.8	1.5	1.8	2.2	1.6	1.8	.....	.....	.....	.....	.....	.....
Woodbury	3	1.9	(a)	1.60	.....	.....	.....	.....	.....	1.80	.....	.....	.....	2.40	.....

a No year given.

THE ISOCHLORS OF NEW YORK.

New York produces more salt than any other State in the Union, and it would be natural to suppose that these salt deposits would affect materially a large portion of the waters in this region. Such, however, has not been found to be the case. In this State the salt beds have only a local influence, and normal waters may be found within a very narrow range of these deposits. The districts from which salt is obtained are, Ithaca, Tompkins County; Le Roy, Genesee County; Syracuse, Onondaga County; Warsaw, Wyoming County, and York, Livingston County.

In all of these districts the normal is below 0.4 part per million, and a water contaminated by salt from these deposits would in most cases be so very much higher in chlorine that it could hardly be mistaken for ordinary pollution.

The determination for the normal chlorine lines of New York State (Pl. V) is the result of analyses made by the author at Mount Prospect laboratory. The time of making analyses extended over a period of six years, and the results represent many thousand determinations of chlorine. The largest number of samples were examined on Long Island, Staten Island, and near the coast on the mainland where the differences in chlorine were greatest over a limited area. It will be seen that the Catskill and Adirondack mountains cause deflections toward the coast in the isochlors. This is due to the precipitation on their southern slopes of the moisture in the lower layers of the atmosphere which naturally contain the greater portion of the salt.

It will also be noted that Long Island has a remarkable effect in lowering the chlorine on the mainland. The lowest isochlor on the mainland is 3 parts per million, whereas if it were not for the protecting influence of the island it would undoubtedly be 6 parts per million. Artesian wells in Manhattan Borough have been found which have a chlorine content of as low as 2 parts per million, but these may be considered to be below normal and to consist of water from some distance north of the point from which they were drawn.

The following is a list of some of the waters which have had an influence upon the establishment of the isochlors for New York State:

Chlorine determinations for New York.

[Parts per million.]

Source.	Chlorine.	Source.	Chlorine.
Albany County:		Livingston County:	
Cooksburg, Catskill Creek	0.4	Sonyea, spring	0.3
Delaware County:		New York County:	
East Branch, reservoir	1.3	Williamsbridge	2.2
East Branch reservoir, Tonnetta Brook	1.3	Orange County:	
Dutchess County:		Middletown, Highland Lake	1.0
Clinton Hollow, Little Wappinger Creek	.6	Mohegan Lake	.9
Fishkill, Whalen Pond	1.0	Tuxedo Park, spring	1.7
Sprout Pond	1.0	Oswego County:	
Millerton, Wobotuck Creek	1.0	Oswego, McKenzies Pond	.3
Franklin County:		Silver Lake	.3
Kushaqua, Lake Kushaqua	.3	Putnam County:	
Saranac Lake, lake	.3	Kirk Lake	1.4
Saranac River	.3	Lake Gilead	1.4
Greene County:		Middle Branch, reservoir	1.4
Ashland, Batavia Kill	.4	Rensselaer County:	
East Durham, Catskill Creek	.5	Troy, Lake Ida	.4
Prattsville, Scoharie Creek	.6	Rockland County:	
Jefferson County:		Hillburn	1.4
Watertown, water supply	.3	Suffern, Mahwah River	1.4
Lewis County:		Ramapo River	1.4
Boyds Corner reservoir, Cold Spring Brook	1.0	Sullivan County:	
Do	1.2	Hasbrouck, Neversink River	.6
		Liberty, spring No. 1	.6

Chlorine determinations in New York—Continued.

[Parts per million.]

Source.	Chlorine.	Source.	Chlorine.
Sullivan County—Continued.		Suffolk County, Long Island—Continued.	
Liberty, spring No. 2	0.7	Babylon, pond	5.1
No. 3	.6	stream	4.0
Ulster County:		stream	4.0
Grand Hotel, station	.4	stream	4.6
Kingston, Esopus Creek	.8	Sumpawampus Creek	4.9
Oakes, Catskill Creek	.4	waterworks	4.8
Randall Bridge, Rondout Creek	.8	well	5.0
Rifton, Black Creek	.6	Brookhaven, Connetquot River	4.6
Shokan, Esopus Creek	.5	Bridghampton, well 1½ miles southeast of station	30.8
Warren County:		Central Islip, well	4.0
Glens Falls, Hudson River	.4	Deer Park, well	4.2
Sodom, reservoir	1.4	East Moriches, Mastic River	5.0
Westchester County:		Great River, Connetquot River	4.0
Croton Lake	1.5	Green Lawn, stream	6.7
Glen Park, pumping station	2.2	Greenport, well	61.8
Katonah, Cross River	1.8	Huntington, stream	7.0
Kensico, reservoir	2.2	town supply	6.2
Muscoot, reservoir	1.5	Kings Park, stream	7.0
Rye Pond	2.6	Islip, Bayshore supply	4.4
Tarrytown, spring	2.9	Beaver Brook	4.1
Yonkers, Grassy Sprain reservoir	2.8	Doxies Stream	4.4
Richmond County, Staten Island:		Orowoc Creek	4.4
Clifton, water supply	6.0	Stellenwerf Stream	4.0
Richmond, Turnpike station, Crystal Water-Supply Company	6.2	well	4.0
Stapleton, water supply	6.0	Long Pond	6.0
Tottenville, water supply	6.0	Melville, well	4.7
Nassau County, Long Island:		Mellville Station, well	4.2
East Meadow Stream	4.6	Manor, stream	7.6
Hempstead, well	3.0	well	4.9
stream at source	3.8	well	6.4
Massapequa, stream	4.0	Moriches, well	7.4
Roslyn, well	4.6	Medford Station, well	5.1
Suffolk County, Long Island:		Mattituck, pond	12.9
Amagansett, well	16.5	Montauk, well	15.8
Aqueboque, well	16.4	Northport, pond	6.0
		town supply	6.0

Chlorine determinations in New York—Continued.

[Parts per million.]

Source.	Chlorine.	Source.	Chlorine.
Suffolk County, Long Island—Continued.		Suffolk County, Long Island—Continued.	
Patchogue, pond	4.6	Sag Harbor, well	17.2
river	4.0	Sayville, Edwards Creek	6.8
Swan Creek	4.4	Patchogue supply	5.0
Tuttle Creek	5.2	Smithtown, stream	4.2
water supply	4.4	Selden, Sumpawampus Creek	4.6
well	6.1	well	5.2
Port Jefferson, town supply	4.4	Wading River, spring	10.0
Ronkonkoma, lake	4.4		

O

PUBLICATIONS OF UNITED STATES GEOLOGICAL SURVEY.

[Water-Supply Paper No. 144.]

The serial publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of United States—folios and separate sheets thereof, (8) Geologic Atlas of United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

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4. Copies of all Government publications are furnished to the principal public libraries in the large cities throughout the United States, where they may be consulted by those interested.

The Professional Papers, Bulletins, and Water-Supply Papers treat of a variety of subjects, and the total number issued is large. They have therefore been classified into the following series: A, Economic geology; B, Descriptive geology; C, Systematic geology and paleontology; D, Petrography and mineralogy; E, Chemistry and physics; F, Geography; G, Miscellaneous; H, Forestry; I, Irrigation; J, Water storage; K, Pumping water; L, Quality of water; M, General hydrographic investigations; N, Water power; O, Underground waters; P, Hydrographic progress reports. This paper is the tenth in Series L, the complete list of which follows. (PP=Professional Paper; B=Bulletin; WS=Water-Supply Paper.)

SERIES L—QUALITY OF WATER.

WS 3. Sewage irrigation, by G. W. Rafter. 1897. 100 pp., 4 pls. (Out of stock.)
WS 22. Sewage irrigation, Pt. II, by G. W. Rafter. 1899. 100 pp., 7 pls. (Out of stock.)
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WS 121. Preliminary report on the pollution of Lake Champlain, by M. O. Leighton. 1905. 119 pp., 13 pls.
WS 144. The normal distribution of chlorine in the natural waters of New York and New England, by D. D. Jackson. 1905. 31 pp., 5 pls.

Correspondence should be addressed to

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

June, 1905.

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Author.

Jackson, Daniel D.

. . . The normal distribution of chlorine in the natural waters of New York and New England, by Daniel D. Jackson. Washington, Gov't print. off., 1905.

31, iii p. v pl. (incl. map) 23cm. (U. S. Geological survey. Water-supply and irrigation paper no. 144)

Subject series: L. Quality of water, 10.

1. Chlorine. 2. Water, Composition of.

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no. 144. Jackson, D. D. The normal distribution of chlorine in the natural waters of New York and New England. 1905.

Reference.

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