GEOLOGICAL SURVEY OF NEW JERSEY

ANNUAL REPORT

OF THE

STATE GEOLOGIST

For the Year 1902.

TRENTON, N. J.:
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HIS EXCELLENCY FRANKLIN MURPHY, Governor, and *ex-officio* President of the Board.................... TRENTON.

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VACANCY ....

II. Congressional District.

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HENRY S. LITTLE† .... MATAWAN.
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WILLIAM F. HALL .... POMPTON LAKES.

VII. Congressional District.

WENDELL P. GARRISON .... ORANGE.
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* Mr. Sinnickson resigned December 2d, 1902.
† Mr. Little resigned February 25th, 1903.
‡ Mr. Taylor died February 17th, 1903.

VIII. Congressional District.

FREDERIC W. STEVENS .... NEWARK.
HARRISON VAN DUYNE .... NEWARK.

IX. Congressional District.

JOSEPH D. BEDLE .... JERSEY CITY.
VACANCY* ....

X. Congressional District.

S. BAYARD DOD .... HOBOKEN.
VACANCY ....

* Mr. George E. Tennant elected to fill this vacancy February 25th, 1903.

To His Excellency Franklin Murphy, Governor of the State of New Jersey and, ex-officio, President of the Board of Managers of the Geological Survey.

SIR—I have the honor to submit my Annual Report upon the work of the Geological Survey for the year 1902.

Yours respectfully,

HENRY B. KÜMMEL,

State Geologist.

TRENTON, N. J., November 29th, 1902.

ADMINISTRATIVE REPORT.

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Administrative Report.

HENRY B. KÜMMEL, STATE GEOLOGIST.

At a meeting of the Board of Managers of the Geological Survey, held January 10th, 1902, the position of State Geologist, made vacant July 1st, 1901, by the resignation of Dr. John C. Smock, was filled by the appointment of Henry B. Kümmel, who had been Acting State Geologist *ad interim*.

A summary of the work of the Survey for the year ending October 31st, 1902, is herewith presented in the Administrative Report, together with certain recommendations which seem to be demanded by the results of investigations. Some of the results of special studies for the year are presented in the accompanying papers.

Administrative work has of necessity taken a large part of the time and attention of the State Geologist. The Survey is in frequent receipt of letters requesting information of one sort or another relating to the resources of the State. In many instances a careful answer necessitates considerable investigation on the part of the State Geologist, either in the reports of the Survey or in the unpublished data. Many of them relate to underground water-supplies and the depth at which water may be obtained. Others concern deposits of peat, clay, cement, rock, &c. In many cases samples are submitted for examination. All such letters are carefully answered and, so far as possible, the desired information is furnished, for it is recognized that this is one of the most important functions of the Survey.

The scientific work of the State Geologist during the year has been varied. In January the iron and copper mines of the State were visited and examined in detail. In the spring some work was done with Professor Salisbury upon the Glacial Geology of Bergen and Passaic counties. In July a short time was spent with Drs. Van Hise and Wolff, of the United States Geological Survey, examining the peculiar problems about Franklin Furnace. Most of the field season, however, was spent in work upon the clay deposits, a part of the time in company with Dr. Ries. In the course of this investigation, all the worked clay deposits of the State were examined, samples collected, factories visited and a detailed map of the Woodbridge clay district partly prepared. Many undeveloped clay properties were also prospected. In this work the detailed information collected by Mr. Knapp, in his work upon the surface deposits, was of great assistance.

The scientific work in the office has been of a varied character. Papers upon the Geology of the Green Pond Mountain Region and upon the Mining Industry were prepared, as well as the Administrative Report for the Annual Report for 1901. The other papers in the report were read in manuscript, and afterwards the entire report read twice in proof, and indexed. Later in the year, Volume V., the Report on Glacial Geology, now in press, was read, first in manuscript, then twice in proof. Some assistance was also given Mr. Salisbury in the preparation of maps to accompany the report. Editorial work on Forestry Bulletins I., II. and III. also demanded some attention. Comparatively little time has been afforded for study of any problems except those immediately in hand.

TOPOGRAPHIC WORK.

Mr. C. C. Vermeule has continued in charge of the topographic and draughting work of the Survey. He has been assisted by Mr. P. D. Staats in the field and Mr. Wm. A. Coriell in the office, but only a portion of their time has been given to Survey work.

The field work has included the completion of the survey of the region about South River and Matawan, which is to serve as a base for a detailed map of the clay deposits. During the last three months of the year Mr. Staats has been engaged in resurveying the northern portion of Sheet No. 7, in Bergen and Passaic counties, a region in which there have been great changes since the original survey in 1887. During the year about 252 square miles have been resurveyed, making a total of 1,515 square miles, or one-fifth the area of the State, now resurveyed, all of which is available for the large scale maps.

In the office, the Trenton and Shark River sheets were completed and the base for the clay map, embracing portions of the New Brunswick, South River and Matawan sheets, was drawn. This work covered about 218 square miles of land surface.

During the year, the Morristown, Atlantic City and Trenton sheets were published, and a new edition of Sheet No. 9 of the old series was issued. The following summary indicates the progress of the work upon the new sheets to date:

Sheets published, 16.

Sheets surveyed and drawn, but not published, 2.

Sheets surveyed, but not completely drawn, 5 (in part).

In addition to work upon the new series of maps, the preparation of illustrations for the Annual Report for 1901 and for Volume V. on Glacial Geology demanded much time.

SURFACE GEOLOGY.

The work on the Surface Geology has continued under the charge of Professor R. D. Salisbury, assisted by Messrs. H. B. Kümmel, G. N. Knapp and C. E. Peet. Mr. Salisbury has been engaged chiefly in completing the manuscript of his report upon the Glacial Geology of the State and in reading the proof sheets. A few days were spent in field work, viewing critical areas. Mr. Peet was engaged in compiling data regarding the glacial deposits of Bergen and Passaic counties, and has completed this work.

Mr. Knapp has been engaged continuously (except during January and a part of March) in field work in southern New Jersey and in office work. The most important scientific problems before the Survey, not only in their bearing upon the geological history of the State, but upon that of the entire Atlantic Coastal plain, are involved in the correct interpretation of the Pleistocene or Surface deposits of South Jersey and their relation to the underlying and older formations. These problems reach a complexity in this State which renders their study extremely interesting, but at the same time extremely difficult. The only hope of finally solving them correctly lies in most detailed and painstaking work, in the course of which all natural and artificial sections are studied, all well data collected and frequent borings made with a hand-auger. Mr. Knapp's work has been of this painstaking character, and, although of necessity proceeding slowly, has been prolific of valuable results. In connection with this work, much information regarding the occurrence of workable clay deposits has been obtained.

The work of the State Geologist in this division has already been noted.

PALEONTOLOGY.

During November and December of 1901, and from July 1st to the close of the year, Dr. Stuart Weller has been engaged in the study and description of the Paleozoic fossils collected during previous years in the northern part of the State. This work has involved the examination of several thousand specimens, the description of several hundred forms, many of which were new to science, and the preparation of fifty-three plates of drawings. In the drawing he has been assisted by Miss Mildred L. Marvin, Miss Annie L. Weller and Mr. D. F. Higgins. His report has been received and will be published as an Appendix to accompany this report.

In March an arrangement was made with Dr. Charles E. Eastman, of the Museum of Comparative Zoology at Cambridge, Mass., to examine and classify the collection of fossil fish obtained at Boonton. This work is being carried on as rapidly as Dr. Eastman's many other studies permit.

CLAY AND CLAY INDUSTRIES.

In September, 1901, Dr. Heinrich Ries, who is a recognized authority on clays, both in this country and abroad, began the preparation of a report upon the economic and technical phases of the Clay Industry of the State. The importance of such a report can be judged from the fact that the annual value of manufactured clay products of the State is over $11,000,000, and that the value of raw clay mined and sold to manufacturers is about $500,000 more.

The report will contain chapters on the following topics: The Origin of Clay—Its Mineralogical and Chemical Composition—Its Physical and Chemical Properties and Their Effects; Prospecting for Clay; Mining Clay; The Technology of the Clay-

Working Industries; The Manufacture of Brick, Terra Cotta, Tile, Conduits, &c.; The Manufacture of Pottery; The Manufacture of Fire-Brick, &c.; New Jersey Clays—Their Geographical Distribution—Their Geological Distribution—Their Physical and Chemical Character—Their Availability and Use; Results of Physical and Chemical Analyses; Tests of Fire Brick and Crushing Tests of Brick. It is planned to include in the report maps showing (*a*) the general occurrence of clay and clay-working industries throughout the State; (*b*) the position of geological formations important as clay-bearing horizons; (*c*) a detailed map of the Woodbridge-Amboy clay district: (*d*) small maps showing the location of clay-beds in selected areas.

Considerable progress has been made in the preparation of this report. Much of the field work has already been done and many of the clay-working establishments have been visited. A large number of samples of raw clay have been collected, and considerable progress has been made in testing these. Not only have samples been taken from localities now being worked, but much prospecting has been done in the hope of aiding the development of new regions. Letters were sent to the newspapers of the State, calling attention to this work and requesting information from owners of undeveloped clay deposits. Numerous answers have been received and much information gained thereby. As many of these localities, as seem promising, will be examined by the Survey and samples of the clay tested.

The manufacture of fire-brick is one of the most important phases of the clay industry in the State. With a view of determining the relation between the chemical composition and the infusibility of fire-brick, samples have been obtained from the manufacturers of the State. These will be analyzed chemically, fused and the results tabulated and published, but without the name of the manufacturer. A report, however, will be rendered each manufacturer regarding the results of his own brick. It is hoped that by these tests, valuable data may be obtained regarding the chemical composition necessary to withstand a given degree of heat.

A series of tests to determine the crushing and breaking strength of common brick, and to afford a comparison of brick made by different processes from the same clay, and of different clays by the same process, has been undertaken. This phase of the work has been in charge of Professor I. C. Woolson, of Columbia University.

It is, of course, impossible to set a date for the completion of this work. It is hoped, however, that the report will be ready for the printer in May or June of the coming year.

ARTESIAN WELLS.

Mr. Lewis Woolman has continued to collect data concerning the artesian wells in the State, particularly in the southern portion, and in part presents a record of the more important of the deep wells drilled during the year. Attention is called particularly to the records of the wells at Hammonton and Cape May. Mr. Woolman's tentative conclusion that the water horizon found at Hammonton at between 230 and 310 feet from the surface is the same as the great Atlantic City water horizon at from 780 to 860 feet is interesting and important. So, too, is the evidence from the Cape May well, that these same beds, which occur at Cape May at 900 feet, are not water-bearing at that point, although they furnish a good supply all along the coast between Harvey Cedars and Wildwood.

FLOODS.

Heavy freshets occurred on many rivers last spring, due to a warm rain on February 28th, following a prolonged cold spell, with considerable snow. On the lower Passaic, particularly, and on the Delaware they were so high and so much damage was done that widespread attention was directed to them. Mr. C. C. Vermeule, whose previous work on the Water Powers of the State had fitted him particularly to investigate the causes and conditions of these floods, was immediately authorized to study them. In the field work he was assisted by Mr. P. D. Staats and Mr. George E. Jenkins. The results of his investigations are given in detail in his report, Part I. of the accompanying papers, but attention is invited here to some of his conclusions.

On the Delaware river, at Easton, the flood was as high as any known at that point, but at Stockton, where there are well authenticated marks, it was four inches lower than the flood of 1841.

On the smaller streams of the State, including the head-waters of the Passaic and Raritan, the water was no higher than in the freshet of 1896 or in 1882, but the 1902 freshet was remarkable in the much longer duration of high water. In consequence of this long-continued heavy run-off, the flat lands on the Passaic, above Little Falls, were covered to such an unusual extent that the freshet reached a dangerous height on the lower Passaic. Here it was higher than any freshet since 1810, although it did not exceed the flood of that date. Since the flood did not reach exceptional heights on the smaller streams, it is certain that the water was not precipitated into them at any unusual rate. This being the case, the extreme height on the lower Passaic cannot be ascribed in any degree to deforestation. Moreover, it is certain that there was as much, if not more, forest in 1810, when the present flood was equaled or exceeded, than at present.

Particular attention is invited to that portion of Mr. Vermeule's report respecting the height of the flood at Little Falls and Paterson, and his conclusions regarding the control exercised by the rock reef and Beattie's dam at Little Falls. These conclusions are of the utmost importance in view of the plans which were made by the Passaic Drainage Commission to lower the dam twenty inches in order to relieve the flat lands above Little Falls. A portion of this work has been accomplished, but its completion has been opposed on the ground that the danger from excessive freshets on the lower Passaic would thereby be greatly increased. This fear arises from an entire misapprehension either (*a*) of the nature of the work contemplated, or (*b*) of the factors controlling the flow of the river during extreme freshets.

Mr. Vermeule's observations show that the discharge of water during great floods, and, therefore, the height of the freshet below Little Falls, is determined solely by the constricted channel between Two Bridges and Beattie's dam, and not by the dam itself nor the reef of rock directly above it. The dam might be entirely removed without materially affecting the height of the water between Little Falls and Paterson during maximum freshets. The flood-marks of last spring's freshet between Little Falls and Two Bridges show conclusively that Beattie's dam exercised no control whatever over the maximum rate of discharge. This conclusion is in entire accord with evidence drawn from observations of the great flood of September, 1882, and of all later freshets. Therefore, the fear that lowering the dam as proposed would endanger Paterson and other points along the lower Passaic is entirely groundless.

Although the proposed improvements would not in any way increase the height of freshets below the dam, nor prevent the meadows from being flooded in extreme high water, nevertheless, they would, if carried to completion, be of great benefit in carrying off the water from the meadows after the maximum stage had passed. Under present conditions the lowlands remain saturated and submerged two or three weeks, or even sometimes months, after the river has passed its flood stage. During this period—*i. e.*, when the stream is bank-full, and discharging about 3,000 to 6,000 cubic feet per second, or one-fifth of its maximum flood discharge—Beattie's dam is a controlling factor in the stream-flow. The proposed lowering of the dam twenty inches and the lowering of the reefs above the dam would at this time give very substantial relief to the wet lands above, and would in no way whatever affect detrimentally the lands below the dam. It is important that these points be emphasized, since so much misapprehension prevails.

Attention is also invited to that part of Mr. Vermeule's report in which he suggests the possibility of creating storage reservoirs along the upper Passaic, whereby the danger of disastrous floods on the lower Passaic may be averted, the value of the existing water powers at Little Falls, Paterson and Dundee enhanced, the summer flow of the river greatly increased and the pollution of the lower river by sewage diminished. The possibilities contained in this suggestion should be thoroughly canvassed in view of the urgent necessity of diminishing the contamination of the Passaic below Paterson.

Mr. Vermeule's full report is commended to the careful attention of all persons interested.

FORESTRY.

During the past year the following Forestry Bulletins have been published and widely distributed: No. I., Forest Reservations in the Pines Belt of Southern New Jersey, by John C. Smock. No. II., Does Forestry in New Jersey Pay? by F. R. Meier. No. III., Practical Aid to Landowners in Handling Forest Lands—A Plan of Co-operation by the Geological Survey. A few copies of each are still available for distribution.

In order that wider knowledge may prevail of the terms upon which the Geological Survey can assist landowners in forestry work, Bulletin III. is herewith reprinted.

PRACTICAL AID TO LANDOWNERS IN HANDLING FOREST LANDS.

A PLAN OF CO-OPERATION BY THE GEOLOGICAL SURVEY.

"Many persons realize that the common methods of treating forest land and harvesting the timber crop are wasteful in the long run, although they seem to yield the greatest immediate returns. A general lack of knowledge as to other methods, however, stands in the way of any widespread improvement. In many European countries forests are systematically treated, and made to yield a continuous income at the same time that the forest, as a whole, is preserved and propagated. For the past eight years forestry methods have been applied to a three-thousand-acre tract in Bergen county, and an annual return of five per cent. has been secured. During the eight years $25,000 worth of timber has been cut off, yet the forest is worth more now than when the experiment commenced, and, under the plan pursued, cutting can continue indefinitely, with equally good results.

In many cases trees may be planted with considerable profit. This is particularly true of the cottonwood, locust, black walnut, catalpa, tulip tree, smooth-bark pine, white pine, and, in some localities, the basket willow. A catalpa plantation, eleven years old, has been known to have a net value of $190 per acre, and a locust plantation, sixteen years old, of $148 per acre. In 1870 a grove of large, thrifty locust trees, thirty-six to thirty-eight years old, near Holmdel, yielded a gross return of $1,200 per acre for fence posts alone, and other instances are known where gross returns of $2,400 per acre have been realized. These results were obtained from the "waste land" on farms.

In order that similar work may be started in other parts of the State and that a better knowledge of forestry methods may prevail, the Geological Survey is prepared to co-operate with landowners to this end, so far as the funds at its disposal may permit.

Upon application from the landowner, the Survey will send a trained forester, who has had practical experience in the management of timber lands in the State, to examine the tract and to give practical advice for the improved treatment of the area in question, either in respect to handling the present forest or in planting for the future.

Many persons think that only wealthy men can afford to place their land under forest management. This is a mistake. The object of forestry is to cut trees in such a manner that valuable successive crops can be raised in the shortest time, without injuring the producing power of the forest, *and at a profit.* The methods to be pursued vary under different conditions, but in all cases one aim is present—*to make the business pay, both now and in the future.* The farmer should be just as much concerned to make his woodlot pay the largest possible profit as he is to secure the largest returns from his orchard or his cornfield. But often this is not the case. The woodlot is left to take care of itself, whereas, in many cases, its value could be greatly increased, with but little additional labor or expense, if wise methods of cutting and planting were pursued.

In various parts of the State there are considerable areas of land which are valueless for agricultural purposes, but which may be of considerable value for forest purposes. These are often held in tracts of one thousand acres or over, but, under present conditions, they are often a source of expense, rather than profit, to their owners.

It is the desire of the Survey to render practical assistance to both classes of owners, and, therefore, requests for advice will be considered for tracts of any size, from five acres upwards. The applications will be considered in the order in which they are received, but precedence may be given to the lands most likely to furnish useful examples.

The conditions under which the Survey will undertake this work are stated in the following agreement:

TIMBERLAND AGREEMENT.

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The Geological Survey of New Jersey and John Doe, of ...., do mutually agree together as follows:

1. The Geological Survey, in pursuance of investigations in forestry, and in order to disseminate a knowledge of improved ways of handling forest lands, shall, after personal study, on the

ground, by its Forester, prepare a plan for harvesting the forest crop and reproducing the forest on the lands of the said John Doe, situated and described as follows: ....
....
....

2. The said plan shall be prepared for the purpose of increasing the present value and usefulness of the said land to its owner and to perpetuate and improve the forest upon it.

3. Upon the completion of the said plan and its acceptance by the said John Doe, the Geological Survey shall supervise the execution thereof, so far as it may deem necessary.

4. The cost of executing the provisions of this agreement shall be paid as follows: (*a*) The salaries of all employes of the Geological Survey engaged in fulfilling this agreement shall be paid by the Survey. (*b*) Actual and necessary expenses for traveling and subsistence of the employes of the Survey working under this agreement shall be paid by the said John Doe. Expenses under this paragraph are estimated for the preparation of this plan at .... dollars. (*c*) The Survey shall not participate, in any degree, in the receipts and expenses arising from said land, further than as specified in (*b*) above.

5. The Geological Survey shall have the right to publish and distribute, in its reports or otherwise, the said plan and its results, for the information of landowners and others whom it may concern.

6. This agreement may be dissolved by either party, upon ten (10) days' notice given to the other.

(Signed) ....
(Signed) ....

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The plan above mentioned, being now completed, is accepted, and will be carried out, under the conditions and during the validity of the above agreement.

(Signed) ....

....

Applicants for advice should specify the acreage and situation of their lands, the latter by county and township. Full details as to the character of the forest are especially desired, in order to avoid delay. Applications may be made at any time, and the State Geologist will be glad to correspond with landowners regarding their properties. The Geological Survey, however, reserves the right to withdraw the offer herein made, without further notice, if the interests of the Survey demand it."

Numerous inquiries have been received in response to this circular and reports have been made to the following persons after an examination of their woodlands by Mr. F. R. Meier, who has acted as consulting Forester to the Survey:

Mr. Edward Colson, Daretown, Salem county; Mr. J. P. Whitney, Glassboro; Mr. Louis Du Bois, Holmdel, Monmouth county; Mr. Morris T. Sherrerd, Engineer and Superintendent of the Newark Water Department.

The largest tract examined was that of the Newark Water Department, surrounding the storage reservoirs in the Pequannock valley, in Passaic, Morris and Sussex counties. On this tract the foremost aim is, of course, the preservation of the water-supply from contamination and the securing of as equable a flow as possible. This is best accomplished by preserving the water-shed in forests, but its attainment is not inconsistent with a scientific and profitable cutting of the timber for revenue. Mr. Meier has examined the tract and outlined a plan of management by which the oldest, diseased and defective trees will be removed to make room for more vigorous growth. Selective cuttings will also be made of trees for the market, and the growth of seedlings will be encouraged. Owing to the great extent of this tract and its consequent importance as an object-lesson in scientific forest management, the Geological Survey has arranged to have Mr. Meier supervise the execution of the plan, in accordance with the terms of the above agreement.

A portion of the land of Mr. Colson was found to be admirably adapted to the cultivation of the basket willow, and accordingly a report regarding its culture was prepared by Mr. Meier. So much of this report as is of general interest is published in Part III. of the accompanying papers.

Forest Fires.—The loss to the State from forest fires has been frequently referred to by the State Geologist. In the Annual Report for 1895 a list of forty-nine fires in Atlantic, Ocean and Burlington counties alone is given, which burned over 60,000 acres and did damage estimated at several hundred thousand dollars. In order to determine exactly the effect of repeated fires upon the forests of the State, accurate valuation surveys were made in 1897 by Mr. Gifford Pinchot, now chief Forester of the United States. These surveys included timber which had been protected from fire and that which had been repeatedly burned over. These showed that the yield of timber from the burned tracts was only one-third the volume of what it would be if protected from fire, and only one-sixth of what the land is capable of producing under careful management. Moreover, under present conditions, the wood is coarse, knotty and fit only for cordwood, whereas, protection from fire would insure dense stands of timber and tall, straight trees, free from knots.

In spite of the facts published in the Annual Reports for 1895, 1898, and 1899, showing the great loss to the State by these fires, which, in the majority of cases, could have been easily extinguished if promptly attacked by an organized force, each year has seen a continuation of the destruction. The past year has been no exception to this rule, although it was marked by heavy rains at intervals during the period when fires are most prevalent, and therefore the damage was not so great as in some years. Nevertheless, the recent investigations of Mr. Meier show that in 1902, from April to October, inclusive, there were sixty-five forest fires in the State, which burned over an area of 98,850 acres and did damage conservatively estimated by him, after actual observation upon the ground, at $168,323. Twenty-one of these were set by locomotives, twenty-two by farmers burning brush or clearing land, six by hunters, two were incendiary and the rest resulted from miscellaneous causes.

During the past year more fires were started by carelessness in burning brush, clearing land, &c., than by locomotives, although the difference in numbers is not great. But when the acreage burned over and the loss are compared we find a marked difference. The twenty-one fires started by locomotives burned 85,203 acres, causing damage to the amount of $110,602, whereas, the twenty-two fires caused by carelessly burning brush swept over 4,495 acres, with loss of $33,976. A single fire in Burlington and Ocean counties, started by a locomotive, swept over a tract twenty miles long and from one to eight miles wide and lasted ten days. The damage by this fire alone is conservatively estimated at $75,000. No effort was made to extinguish it and it was finally put out by rain. The most destructive fire caused by burning brush was one near Bridgeton, where 800 acres of thirty-year old oak and pine of excellent quality were burned, causing a loss of $16,000. Leaving these two fires out of account as perhaps being unusual, we nevertheless find that the twenty other fires set by locomotives burned 10,203 acres, with loss of $35,602, as against the twenty-one other fires from burning brush, which burned only 3,695 acres, with loss of $17,976. It is evident, therefore, that the fires caused by railroads were last year by far the most destructive, although not the most numerous.

The reason for this is perhaps twofold. Fires started by burning brush or clearing land are frequently confined to more or less isolated tracts of timber and therefore cannot spread so widely. Moreover, it more often happens that some effort is made to extinguish these fires or at least to confine them within limits. In the case of the railroad fires, however, these more commonly start in the great unbroken stretches of pine, where houses are almost entirely wanting. Unless discovered promptly by the railroad section men, no efforts are ordinarily made to extinguish them. The smoke, indeed, is commonly seen from the nearest town, but it is no one's business to fight the fire and, therefore, no attention is paid to it unless it threatens the town. Nearly all the fires during the past year could have been extinguished with little loss, if attacked promptly by a well-organized force under competent direction.

Arranged by counties, the record stands as follows:

Atlantic	11	fires,	11,417	acres	burned,	damage,	$32,463	00
*Burlington	5	"	25,128	"	"	"	25,100	00
Cape May	13	"	1,950	"	"	"	4,705	00
Cumberland	7	"	3,225	"	"	"	28,018	00
Camden	1	"	400	"	"	"	6,000	00
Gloucester	5	"	830	"	"	"	4,220	00
Mercer	1	"	15	"	"	"	150	00
Monmouth	2	"	620	"	"	"	5,900	00
*Ocean	5	"	53,080	"	"	"	54,297	00
Passaic	2	"	1,125	"	"	"	4,500	00
Morris	1	"	350	"	"	"	700	00
Salem	4	"	480	"	"	"	2,480	00
Somerset	5	"	100	"	"	"	400	00
Sussex	4	"	130	"	"	"	390	00
							$168,323	00

* One fire is counted in both Burlington and Ocean counties.

The above estimates take into account only the damage to the timber itself, but do not include the less easily estimated damage done to the soil, which is impoverished by repeated burnings. The layer of vegetable mold which is always found on the floor of undisturbed forests and which is vitally necessary to the propagation and growth of the forest, is gradually destroyed by repeated burnings. It is recognized by all foresters that this layer of humus is an important factor in preventing evaporation from the soil, moderating extremes of temperature and preventing the shifting of the sand beneath by wind and rain. If this is destroyed the reproduction of the forest is practically impossible for many years. In some parts of the pines belt, this condition has already been reached, and in all regions subject to repeated fires it is rapidly approaching. The annual damage done by fires in destroying the humus is not easily expressed in dollars and cents, but it must not be overlooked.

Many persons are inclined to question the damage caused by these fires which annually sweep over portions of the State. The reason for this is that the freshly devastated lands are compared with the forests which are now in existence, and which, for the most part, have themselves been burned over repeatedly. This is wrong. Comparison should be made with the forests which grew originally or which might still be flourishing if the land had been protected. Small, scattered tracts of old timber have locally escaped fire and demonstrate by their size and value that the soil, where not sterilized by repeated burnings, is capable of producing a large tree growth. On the other hand, treeless, nearly barren areas, like the Plains in Burlington and Ocean counties, show the results of repeated fires, and indicate only too surely the condition to which a large portion of the pines belt will ultimately be reduced unless forest fires are prevented. As eminent an authority as Mr. Gifford Pinchot has declared that "the complete impoverishment of southern New Jersey is close at hand unless the fires can be stopped."

Methods of Prevention.—Under existing legislation, the duty of fighting forest fires has been left to the townships. They have had power to appoint fire marshals and make appropriations for this work, but no effective good has been accomplished. As shown by the number and extent of fires during the past season, the means at present employed are totally inadequate. Very few of the townships make any effort to prevent or extinguish fires, leaving it to individual effort. Not a single township has availed itself of the provisions of the law* passed by the last Legislature, nor has any determined effort been made to enforce its regulations regarding the burning of brush, charcoal pits, &c., which caused over 30 per cent. of the fires last year. In the opinion of some, not five townships will accept the provisions of the act in the next ten years.

Individual effort is totally ineffective in the vast majority of cases, for a variety of reasons. The most serious objections to the present methods of fire-fighting are (*a*) lack of unity of effort and centralization of authority; (*b*) general apathy, except where the fire has attained great proportions and threatens some town or farm buildings; (*c*) lack of knowledge as to exact location of the fire in its incipient stages; (*d*) delay in attacking the fire; (*e*) frequent cessation of efforts before the fire is completely extinguished.

In the Annual Report of the State Geologist for 1898, after the whole subject had received careful investigation, a comprehensive plan was presented for a State Forest Service. It was there shown that successful organization against fires should attain (1) the rapid and accurate location of the fire; (2) the speedy arrival of the fighters at the scene of a fire, and (3) vigorous and intelligent action on the part of the fighters. Whether the proposed plan was the best that could be devised, or whether a simpler organization might not be equally effective, is a question which can only be determined after trial. It is beyond question, however, that no effective measures against forest fires can be expected within the next decade unless the State takes the matter in hand. The studies of this department indicate that a maximum annual expenditure of $10,000 by the State in establishing and maintaining a State Forest Service will largely prevent this annual devastation. Since the area to be protected is, roughly, 1,400,000 acres, the expenditure of about three-quarters of a cent per acre per annum cannot be regarded as excessive.

The organization should have an expert forester at its head, who should not only have charge of all efforts in fighting fires, as well as the enforcement of the forest laws, but should also give advice and instruction, free of charge, to residents of the State,

*An act concerning forest fires and the prevention thereof. Chapter 139, Laws of 1902.

upon all matters relating to the protection, care and management of woodlands, both by letter and by personal inspection of forest areas, and who, by all means in his power, should create an enlightened public sentiment on forestry matters.

There should also be numerous fire wardens, at points throughout the region subject to fires, who, in consideration of a small sum monthly, should bind themselves to fight fires whenever they occur within their territory. Provision should also be made for the temporary employment of large numbers of men to fight great fires, which cannot be extinguished except by a large force. It is not intended here to present the plan in all its details, but only to emphasize the conviction of the State Geologist and various members of the Survey staff, reached after careful study and consultation with many persons familiar with the conditons, that a State Service organized along these lines, with the right kind of officers, would not only be efficient in extinguishing fires before they had attained great headway, but that it would arouse public opinion to the usefulness of forests and the danger which threatens them. The safety of the forests in any region must ultimately rest upon an enlightened local sentiment, and without this, efforts to protect them cannot be entirely successful.

Since local measures are not effective; since the matter is beyond the power of townships to control; since the increasing devastation is a matter which concerns the State at large as well as the regions immediately affected, the State, out of its abundant resources, should promptly establish a forest-fire service. The question cannot be solved by postponing action, for postponement only aggravates existing conditions. Prompt and efficient action is demanded, and the demand should not go unheeded. Some such plan as that proposed above should be put in operation at once, in the district most exposed to fire. The State annually spends thousands of dollars to enforce the game laws and protect the game from extinction, although, at the same time, large amounts of game are annually killed by these fires. It surely should exercise its police powers to preserve its forests, which are of great value and importance, not only for the production of timber, &c., but for their indirect effects upon the soil, the water-supply and the climate.

CO-OPERATION OF THE UNITED STATES GEOLOGICAL SURVEY.

Under the agreement entered into in 1891 with the United States Geological Survey for co-operation in geological work, a portion of the Highlands was surveyed in four succeeding years, but work was suspended for a number of years. During the past season, however, at the urgent request of the State Geologist, it was resumed. The Franklin folio, showing the geology of a considerable region around Franklin Furnace, together with descriptive text, has been prepared by Dr. J. E. Wolff for publication by the United States Geological Survey, and is now in the hands of the engravers.

Under Dr. Wolff's direction, moreover, field work was continued in the Highlands, with a view of completing the area contained in the Passaic quadrangle of the United States Survey maps. Upon the completion of this work, data will be in hand for the publication of another folio, which will show the geology of another large area, in the northern part of the State. The expense of this work is borne by the national organization, thus permitting the funds of the State Survey to be used in other directions.

The Hydrographic branch of the United States Geological Survey, in response to requests from many leading citizens of the State, as well as from the State Geological Survey, late in the year, made arrangements for a series of stream measurements upon New Jersey rivers, for the purpose of determining the stream-flow during the various stages of high and low water. This work supplements and carries forward that already done by this department, the results of which were presented in Mr. C. C. Vermeule's Report upon the Water-Supply, Volume III. of the Final Report series.

MUSEUM.

Early in the year the cases and specimens which had been on exhibition at the Pan-American Exposition were returned from Buffalo and replaced in the Museum. Owing to lack of cases and shelves, much of the new material, secured for exhibition at Buffalo, cannot be displayed to advantage. The same is also true of the new material which is constantly coming into possession of the Survey. Under present conditions, there is nothing to be done but to store this material in boxes in the basement of the State House.

LIBRARY.

The Survey receives, as exchanges, reports and maps from other Surveys, both in this country and abroad, as well as numerous trade journals and pamphlets from individuals. In addition to these, several important geological and mining periodicals are received by subscription, and some important books needed for reference are purchased.

In these ways the Library received during the year 27 bound volumes, over 200 unbound volumes of periodicals and reports, 326 pamphlets and nearly 200 engraved maps. The proper care of these, even with the minimum amount of attention and simplest method, demands considerable time.

PUBLICATIONS.

During the year, the Annual Report for 1900, an 8vo, containing XXVIII. plus 178 pages, and illustrated with six inset plates, two figures in the text and two maps, has been published and was distributed in July. The exchange list of the Survey contains the names of 285 libraries and other surveys, 332 newspapers and periodicals and 2,945 individuals. All requests for reports are filled so far as the supply on hand permits, the only expense to the recipient being the cost of transportation. The demand for the reports from parties without the State, wishing information as to its resources, is large and encouraging.

Three forestry bulletins have been published and distributed—Bulletin I., Forest Reservations in the Pines Belt of Southern New Jersey, by J. C. Smock, 12 pages, 1 map; Bulletin II., Does Forestry in New Jersey Pay? by F. R. Meier, 9 pages; Bulletin III., Practical Aid to Landowners in Handling Forest Lands—A Plan of Co-operation by the Geological Survey, 6 pages.

The Report on Glacial Geology, Volume V. of the Final Report series, is in press at this writing, and will be ready for distribution soon.

The following sheets of the large scale maps were published during the year: Morristown, in December, Atlantic City, in October, and Trenton sheet just after the year closed. Copies of these sheets have been sent to a few libraries in the State, to other Geological Surveys, to the Managers of the Survey, and to the various State departments. Further distribution is by sale at the regular charge of 25 cents per sheet—a charge which barely covers the cost of printing and mailing.

A new edition of sheet No. 9 of the old Topographical Atlas was also issued and placed on sale.

PART I.

Report on the Floods of February 28th to March 5th, 1902.—Effect of Proposed Drainage Works on Passaic Floods.

By C. C. VERMEULE.

Notes of the Floods of February 28th to March 5th, 1902.—Effect of Proposed Drainage Works on Passaic Floods.

BY C. C. VERMEULE.

On the opening days of March last there were freshets on all of the streams of the northern part of the State which were high enough to be worthy of study and comparison with previous high floods. They did not, as a rule, exceed in height previous floods of record. On the lower Passaic, however, the flood was the highest since 1810, and considerable damage was done at Paterson.

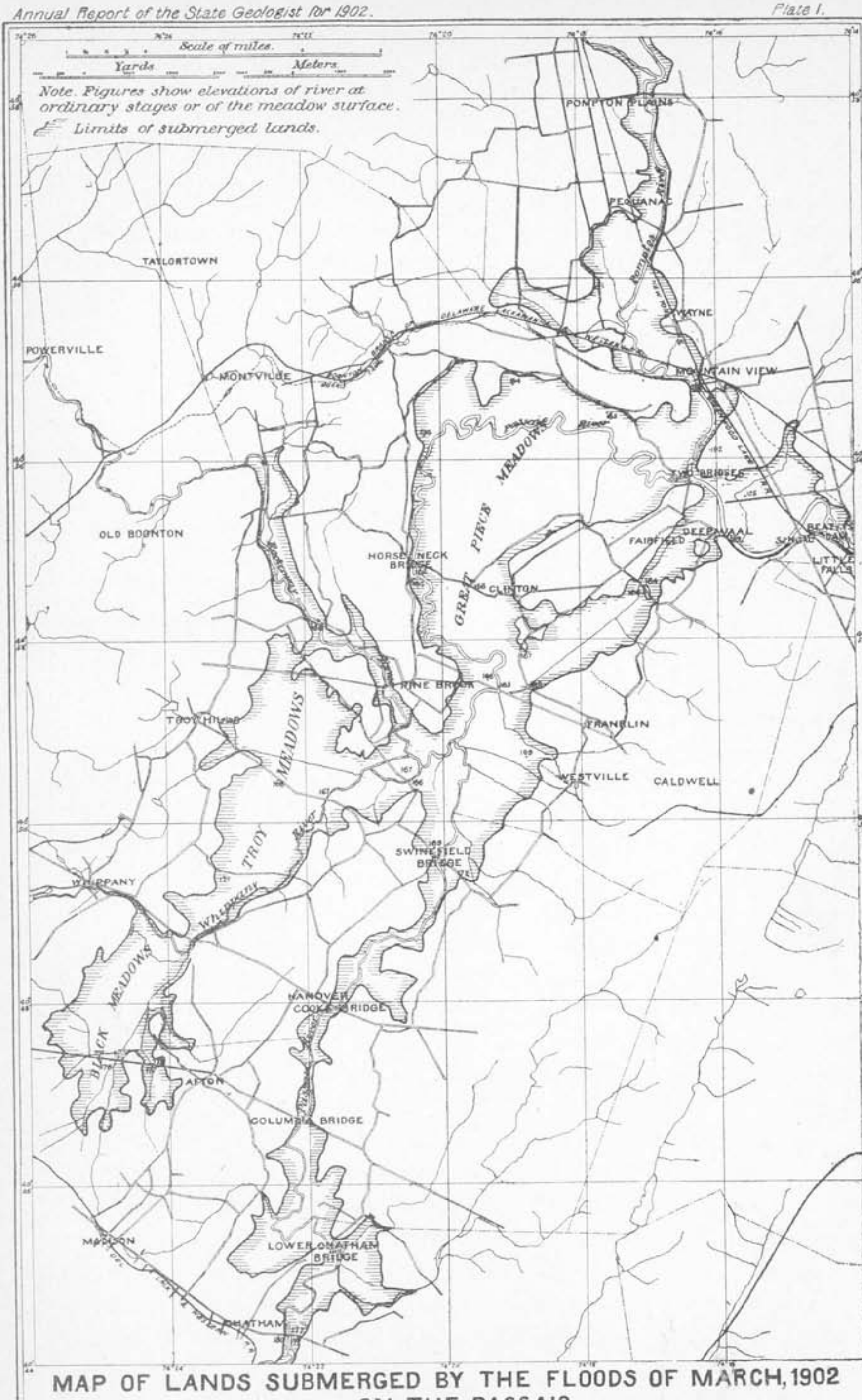
When the Report on Water-Supply, of 1894, was written, the flood of September, 1882, on the Passaic, was taken as a maximum, and there appeared to be no evidence that any higher water had occurred on that stream or on the Raritan, and possibly none so high, except in 1810. On February 6th, 1896, however, freshets occurred which were discussed in the annual report for that year. These were higher on the Raritan and the several Highlands branches of the Passaic than any previous freshets for which we have reliable data; but on the Passaic, below Two Bridges, the water was not so high in 1896 as it was in 1882. We are again called on six years later to record another notably high freshet, and it becomes interesting to investigate its cause, and endeavor to ascertain whether there is any reason to infer that similar high freshets are occurring more frequently than during the early part of the nineteenth century.

It is well to direct our attention first to the meteorological conditions which produced the freshets of last March. The precipitation through the winter had been fully up to the normal;

and, as is usual in the month of February, the ground was well filled with water. The entire month of February was cold, averaging 4 degrees below the normal temperature, and there had been, from the 21st to the 26th, precipitation amounting to 2.65 inches in all. The weather, up to the 26th, had been so cold that practically all of this water must have remained on the ground in the form of snow or ice. The snow, which was compact, ranged from 8 inches to 1 foot in depth on the 28th. On the 25th the mean daily temperature of the Highlands was 26.5 degrees; on the 27th it had risen to 43 degrees. The streams began to rise early on the 26th and were already out of their banks on the morning of the 28th, on which day the average rainfall in the northern part of the State amounted to 1.61 inches, and the rivers rose rapidly. This was followed by 0.91 inches additional on the 1st and 2d, and 1.05 inches on the 5th of March, making the total precipitation 6.22 inches.

As a result of these conditions, during the eight days from February 28th to March 7th, inclusive, the Passaic discharged over Dundee dam 86 per cent. of this precipitation, or a quantity of water equal to 5.35 inches of rainfall on its catchment. This flood, therefore, exceeds in volume the greatest previous one for which we have a volumetric record, viz.: September, 1882, by over 44 per cent. Fortunately, the rainfall and the thaw were distributed over eight days, and precipitation was not so concentrated as in February, 1896; consequently the maximum rate of discharge and the height of this flood were not commensurate with its great volume, and exceeded that of 1882 on the Lower Passaic by only 24 per cent.

On the Delaware the flood of last March was 9 inches lower at Lambertville, and 4 inches lower at Stockton, than the flood of 1841. On the Raritan and most of the other streams of Northern New Jersey it was also lower than in 1896. Only the Lower Passaic, Delaware and Pequest exceeded the records of 1896 and 1882. On these, owing to topographic peculiarities, the maximum rate of discharge is more nearly commensurate with the volume of run-off than is the case with more torrential streams.



MAP OF LANDS SUBMERGED BY THE FLOODS OF MARCH, 1902 ON THE PASSAIC.

PASSAIC CATCHMENT.

The topography of the Central Passaic Valley and the relative position of the several branches of the Passaic are shown by Plate I. Between Two Bridges and tidewater, at the city of Passaic, the stream receives no important affluent. This portion of the stream we have designated the Lower Passaic. We have records of its discharge at Little Falls and Dundee, and of its height at Paterson, all of which are in close agreement.

Two Bridges is at the confluence of two branches having nearly equal catchments, viz.: the Pompton and the Upper Passaic.

The northerly affluent, the Pompton, is formed by the confluence of the Ramapo, Wanaque and Pequannock, all of which meet about six miles north of Two Bridges, at the village of Pompton. The catchment of the Pompton, which lies mostly upon the Northern Highlands, is mountainous and forested. There is very limited opportunity for the flood-waters to spread and accumulate, as the valleys above Pompton are narrow and confined, consequently the floods are discharged promptly and the maximum rate of discharge is high. The southerly affluent, the Upper Passaic, has large areas of flat land over which the flood-waters spread as indicated by the shading in Plate I. These flats extend to include Great Swamp, not shown on Plate I., which is almost at the head-waters of the stream, but two important branches, the Rockaway and Whippany, have their catchments upon the Southern Highlands, so that about one-half of the catchment of the Upper Passaic is hilly or rolling, with considerable forest area.

The Passaic below Two Bridges reached the bank full stage of 4,000 cubic feet per second at midnight on the 26th of last February, and by noon on the 28th had risen to over 12,000 cubic feet per second. It then began to rise more rapidly, reaching a maximum of 22,677 cubic feet per second on March 2d, at 6:30 P. M. It continued at a very high stage, exceeding 21,000 cubic feet per second, for 24 hours, or until 6:30 P. M. on March 3d, after which it subsided in its customary, regular, but tardy manner. Owing to later rains the river did not get within its banks for about two weeks, but the flood which we are considering was practically over by 6:30 P. M. of March 7th. During the eight days from February 28th to March 7th, inclusive, the total quantity of water flowing over Dundee dam amounted to 10,-219,443,630 cubic feet. This quantity can be better understood if we consider that it would fill a square reservoir measuring one mile on each side and 366 feet deep. It would be sufficient, if stored and saved, to supply all the water used by Newark and Jersey City together for a period of over three years; but, for reasons which we have pointed out in the Report on Water-Supply, it is impracticable to conserve such flood-waters.

This year's flood on the Lower Passaic exceeded all others which we have heretofore recorded in any of these reports. During our studies of this flood, however, we have been able to verify marks of the flood of 1810 which have been pointed out from time to time, and have obtained other marks. From these we find that flood to have been six-tenths of a foot higher between Little Falls and Two Bridges than the recent freshet. An accurate survey of the channel of this part of the river, and well-ascertained slopes of these floods, enable us to compute that the maximum discharge in 1810 must have been 25,500 cubic feet per second, or 10 per cent. in excess of the flood of 1902.

It also appears that about forty years ago there was another freshet nearly as high as that of 1902. (There was such a flood on the Raritan in 1865. See Report on Water-Supply, page 214.)

The following tables exhibit in condensed form the leading data for the high freshets of which we have measurements:

TABLE A.

MAXIMUM RATES OF DISCHARGE ON THE PASSAIC AND ITS BRANCHES.

	Catchment, square miles.	SEPTEMBER 22, 1882.		FEBRUARY 6, 1896.		MARCH 2, 1902.	
		Hours beginning to maximum.	Greatest discharge cubic feet, per second.	Hours beginning to maximum.	Greatest discharge, cubic feet, per second.	Hours beginning to maximum.	Greatest discharge, cubic feet, per second.
Passaic, Dundee....................	822	66	18,265	44	17,217	91	22,677
" Little Falls........... ...	773	66	19,000	44	16,745	81	21,207
Ramapo, at Pompton..........	160	24	10,540	24	8,731	54	7,049
Wanaque, at Pompton...............	101	24	6,666	11	7,203	54	6,187
Pequannock at Pompton..........	85	20	4,460	7	5,500	50	4,600
Rockaway at Boonton	118	36	4,800	16	5,445	51	4,540
Whippany at Whippany............	38	...	.....	10	3,200	47	2,600

TABLE B.

GREAT FLOODS ON THE PASSAIC AT DUNDEE SINCE 1876.

AREA OF WATERSHED 822.7 SQUARE MILES.

DATE OF MAXIMUM DISCHARGE.	GREATEST DISCHARGE, CUBIC FEET, PER SECOND.	TIME FROM BEGINNING OF RISE TO—		TOTAL DISCHARGE.	
		Maximum, hours.	End, days.	In million cubic feet.	Inches on watershed
March 2d, 1902......................	22,677	91	8	10,219	5.35
September 25th, 1882..............	18,265	66	8	7,101	3.71
February 8th, 1896...........	17,217	44	8	6,083	3.18
December 12th, 1878...............	16,592	60	8	6,878	3.47
February 14th, 1886...............	12,452	60	8	5,729	3.00

Table A shows, in the columns headed "hours from the beginning to the maximum," the relative suddenness of the rise of the three great floods on any given stream. Thus, the very sudden, sharp rise of 1896 brought the main stream to a maximum at Dundee in 44 hours, whereas in 1902 it required 91 hours. On the branches the variation was still greater. In both cases the ground was frozen, but thawing, yet the contrast between the two is much sharper than between either and the September freshet of 1882. This makes clear the fact that the deficient percolation due to frozen earth, to which too much importance is often attached, is less of a factor than the degree of concentration of rainfall. In considering the rate of precipitation we must, of course, treat all snow and ice accumulations as rainfall at the time when they were set free by melting. Another very important factor is the condition of the ground-water. A concentrated rainfall coming upon saturated soil will produce heavy floods at any season of the year.

As will be seen by reference to Table A, all of the branches reached a higher maximum in 1896 than they did in 1902; but, on the other hand, the main stream at Dundee and Little Falls was lower. A reference to Table B will show, on the other hand, that the total run-off of the stream during eight days was very much greater in 1902 than in 1896. This seeming paradox is fully explained by the fact that the maximum height on the branches is determined by the greater or less concentration of the precipitation, whereas on the lower stream the height of the maximum is determined by the extent to which the Great Piece meadow above Two Bridges is filled up, owing to the excess of inflow over the capacity of the channel below Two Bridges.

Taking the column of hours for a given flood, we have an exhibit of the chronological order or sequence of the maxima on the several branches and on the main stream. In order better to understand the movement of the flood-waters into and out of the large swamps on the river above Two Bridges, it is necessary to present more fully the sequence of the flood stages on the several branches, and this is done for the two floods of 1902 and 1896 in the two following tables:

TABLE C.

CHRONOLOGY OF THE FLOOD OF 1902 ON THE PASSAIC.

POINT OF OBSERVATION.	HOURS FROM FEBRUARY 26TH, 1902, MIDNIGHT, WHEN THE PASSAIC REACHED BANK-FULL STAGE TO—			
	Beginning of rapid rise.	Maximum height.	Beginning of marked subsidence.	End of flood.
Passaic, at Little Falls	Uniform.	81	96	9 days.
Pompton, at Pompton Plains	"	54	72	7 "
Ramapo, at Pompton	38	48	57	....
Wanaque, at Pompton	42	92	95	....
Pequannock, at Pompton	36	48	120	....
Rockaway, at Boonton	43	51	101	....
Rockaway, at Pine Brook	Uniform	78	78	....
Whippany, at Whippany	42	47	47	7 days.
Passaic, at Hanover	Uniform.	96	104	9 "
Passaic, at Chatham	"	36	66	9 "

TABLE D.

CHRONOLOGY OF THE FLOOD OF 1896 ON THE PASSAIC.

POINT OF OBSERVATION.	HOURS FROM BEGINNING OF RISE ON THE PASSAIC, FEBRUARY 6TH, 1896, AT 10 A. M. TO—			
	Beginning of rapid rise.	Maximum height.	Beginning of marked subsidence.	End of flood.
Passaic, at Little Falls	3	44	44	6 days
Pompton, at Pompton Plains	Uniform.	13	Uniform.	66 hours.
Ramapo, at Pompton	"	23	"	3 days.
Wanaque, at Pompton	"	23	"	36 hours.
Pequannock, at Pompton	"	6½	"	24 "
Rockaway, at Boonton	"	16	17	48 "
Whippany, at Whippany	"	10	Uniform.	21 "
Passaic, at Pine Brook	7	17	41	6 days.
Passaic, at Hanover	Uniform.	24	36	6 "
Passaic, at Chatham	"	5½	53	....

3

For the flood of 1902 we have reckoned time from midnight terminating the 26th of February, when the Passaic reached 4,000 cubic feet per second, which is the bank-full stage at Two Bridges. For the 1896 flood we have taken the beginning of the rise, which was sudden and distinctly marked, as at that time the river was considerably below the bank-full stage.

The time of maximum height at the upper end of the flat lands is indicated by the record at Pompton Plains, Boonton, Whippany and Chatham. We have found that, in 1902, the maximum height was reached at these points in from 36 to 54 hours, the average being 47 hours, whereas the maximum height at Little Falls and Two Bridges, on the Lower Passaic, did not occur until the expiration of 81 hours, or 34 hours later than at the head of the flats. In 1896, the maximum at the head of the flats occurred at an average of only 11 hours from the beginning, whereas the maximum on the Lower Passaic was not reached until 44 hours had expired, a difference of 33 hours. The *agreement in time lapsed* between high water at the head of the flats and high water at the outlet at Two Bridges is marked in spite of the very great difference in the other characteristics of these two floods. As the difference of time was the same during the flood of September, 1882, it would appear that the time required for the flood to come down across the flats to Two Bridges is constant and independent of the height of the flood.

The swamp lands above Two Bridges and below Chatham, which are shown as submerged on Plate I., aggregate about 20,000 acres. The area of land covered with water during the flood of 1882 was determined by survey, and amounted to 20,012 acres. Our computations of the flood of 1882 indicated that at the end of 72 hours, or 3 days after the beginning of the rise, by which time the several branches had subsided within their banks, the accumulation of water on the flats amounted to 3,480,000,000 cubic feet. A similar computation for the flood of 1896 shows that the greatest accumulation was at the end of 24 hours, and amounted to only 1,880,000,000 cubic feet, which accumulation was not materially diminished until after the expiration of 48 hours. (See annual Report for 1896, page 267.) Our studies of the flood of 1902 indicate that the accumulation on the flats at the expiration of 60 hours amounted to 1,734,-

000,000 cubic feet. At the end of 90 hours the accumulation was 1,272,000,000 cubic feet. From these figures it appears that the unusual height of the flood below Two Bridges was due, not to an unusual accumulation of water on the flats as a whole, but to the fact that after this water had begun to move down into Great Piece meadow, above Two Bridges, it was augmented unusually by the continued high rate of discharge of the branches, due to the successive storms, so that Great Piece meadow, immediately above Two Bridges, was filled up to an unusual degree, causing a high rate of discharge through the restricted channel from Two Bridges to Little Falls.

It must not be inferred that the submerged area shown on Plate I. was at any time level, like a lake, over the entire expanse. The slope of the flat lands is indicated by the elevations shown by the figures, which in some cases indicate the ordinary water level of the stream and in other cases the average level of the meadow surface. As shown by our chronology of the flood, in Tables C and D, high water occurred earliest at the points where the several branches come into the flats; and at this time, which was about midnight of the 28th, it was still 4.5 feet below its maximum height at Two Bridges, consequently there was a marked slope of its surface down through the flats, considerably greater than the slope of the valley. For 34 hours later, until the maximum discharge was reached at Little Falls, the water was subsiding at the upper end of the great pool, but rising at Two Bridges. During the next 15 hours it was discharged at Two Bridges as fast as it came in from above, and the out-flow was nearly constant. After this the discharge could be no longer maintained and the stream declined as it gradually emptied the flats of the accumulated flood-waters.

In the Annual Report for 1896 we traced the history of the flood of February 6th, 1896, and that of the flood of September, 1882, was traversed in the Report on Water-Supply of 1894 (page 155). The freshet of March, 1902, is less readily analyzed because of complications arising from the repeated heavy rains, but sufficient data have been collected to enable us to show graphically in Plate II. something of the history of the flood. On this plate the vertical lines and figures at the top indicate the date and hour, the lines being drawn at midnight, 6 A. M., noon and 6 P. M., for each day. The horizontal lines and figures at the left indicate the discharge in cubic feet per second on the several streams, so that such discharge can be found for any given hour during the flood.

Line "a" shows the curve of measured flow of the Passaic at Dundee dam, where the measurements are more satisfactory than at Little Falls, during the entire period of the flood. We have sufficient data at Little Falls to show that the curve of discharge there is closely parallel to the curve at Dundee. The discharge at Little Falls dam appears to have been remarkably steady from 9 A. M. to 12 P. M. of March 2d, varying but slightly from the maximum. Line "b" shows the curve of discharge of Pompton river at Two Bridges. This curve is a composite, made up of data obtained on the Ramapo at Pompton Steel Works, on the Wanaque at Pompton Lakes, and on the Pequannock above Pompton, together with a record kept at the head of Pompton feeder. We have been able to approximate closely the discharge of the Pompton from these data. Line "c" shows the rate at which the water came in from the Upper Passaic at Two Bridges.

The flood-waters of the Pompton reach Two Bridges much quicker than those from the other branches of the Passaic, as the latter have to work their way across a large area of flat land which must first be filled up to a sufficient height. As we have previously pointed out, (see Report on Water-Supply, page 155; also Annual Report for 1896, page 268) the result of this is that the flood-waters from the Pompton frequently flow up the southerly branch of the Passaic into the Great Piece meadow, this retrograde flow continuing until equilibrium has been established by filling up of the Great Piece meadow.

In Plate II., after having established the curve represented by the flow of the Pompton, shown by the line marked "b," we have taken the difference between the flow shown by this curve and the measured flow of the Lower Passaic, to represent the discharge of the Passaic past Two Bridges, and in this way have obtained the data to plot line "c." It will be noted that from about 10 P. M. on the 28th until 2 P. M. on March 1st, this curve goes below the horizontal line marked "0 cubic feet per second," or the line of no discharge. The reason for this is that during that time the flow of the Pompton past Two Bridges exceeded the

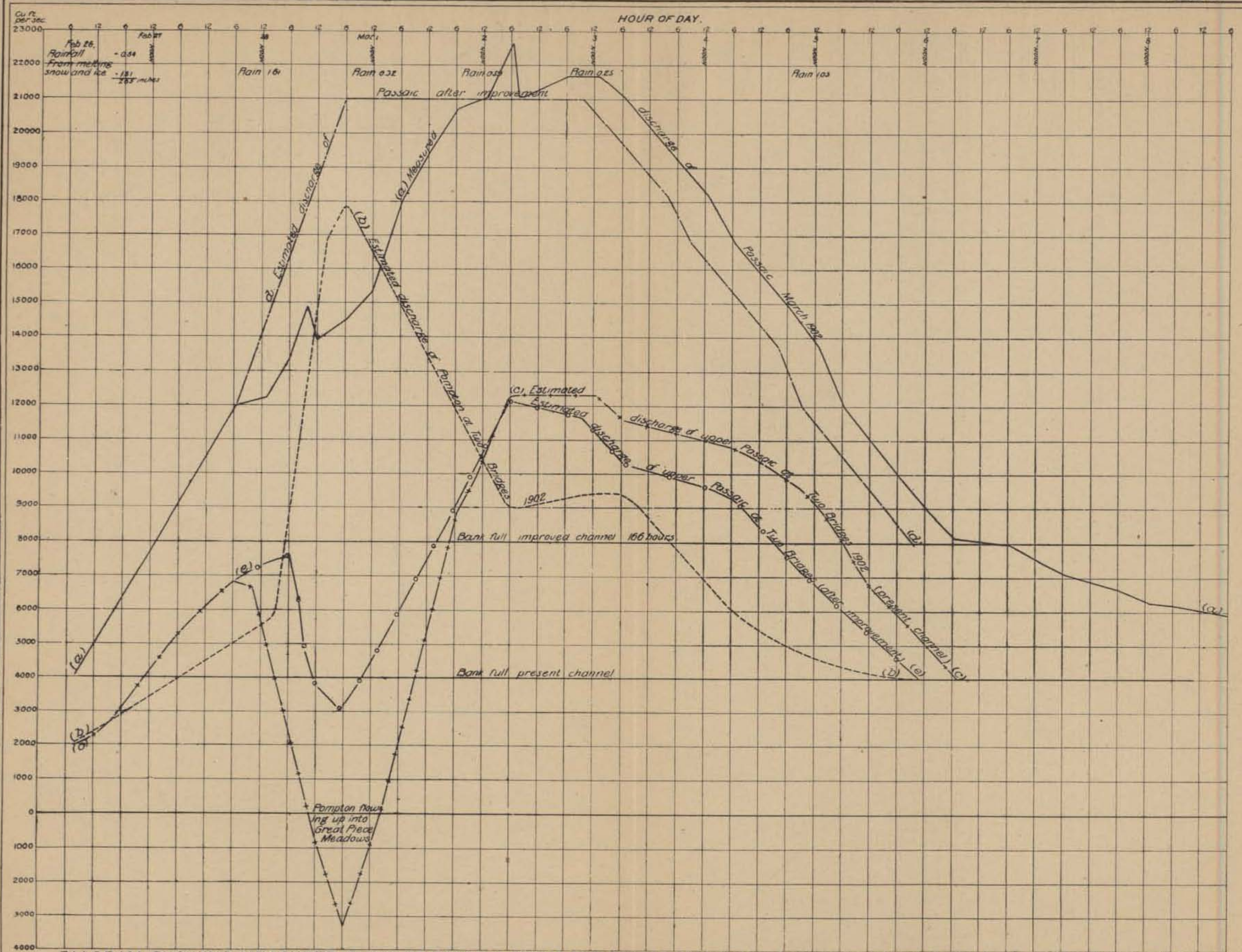


DIAGRAM SHOWING MEASURED FLOW OF PASSAIC RIVER FEB. 27TH TO MAR. 9TH 1902 AND THE ESTIMATED FLOW OF ITS TWO TRIBUTARIES AT TWO BRIDGES. ALSO ESTIMATED FLOW OF THE PASSAIC AFTER COMPLETION OF PROPOSED DRAINAGE WORKS ABOVE LITTLE FALLS.

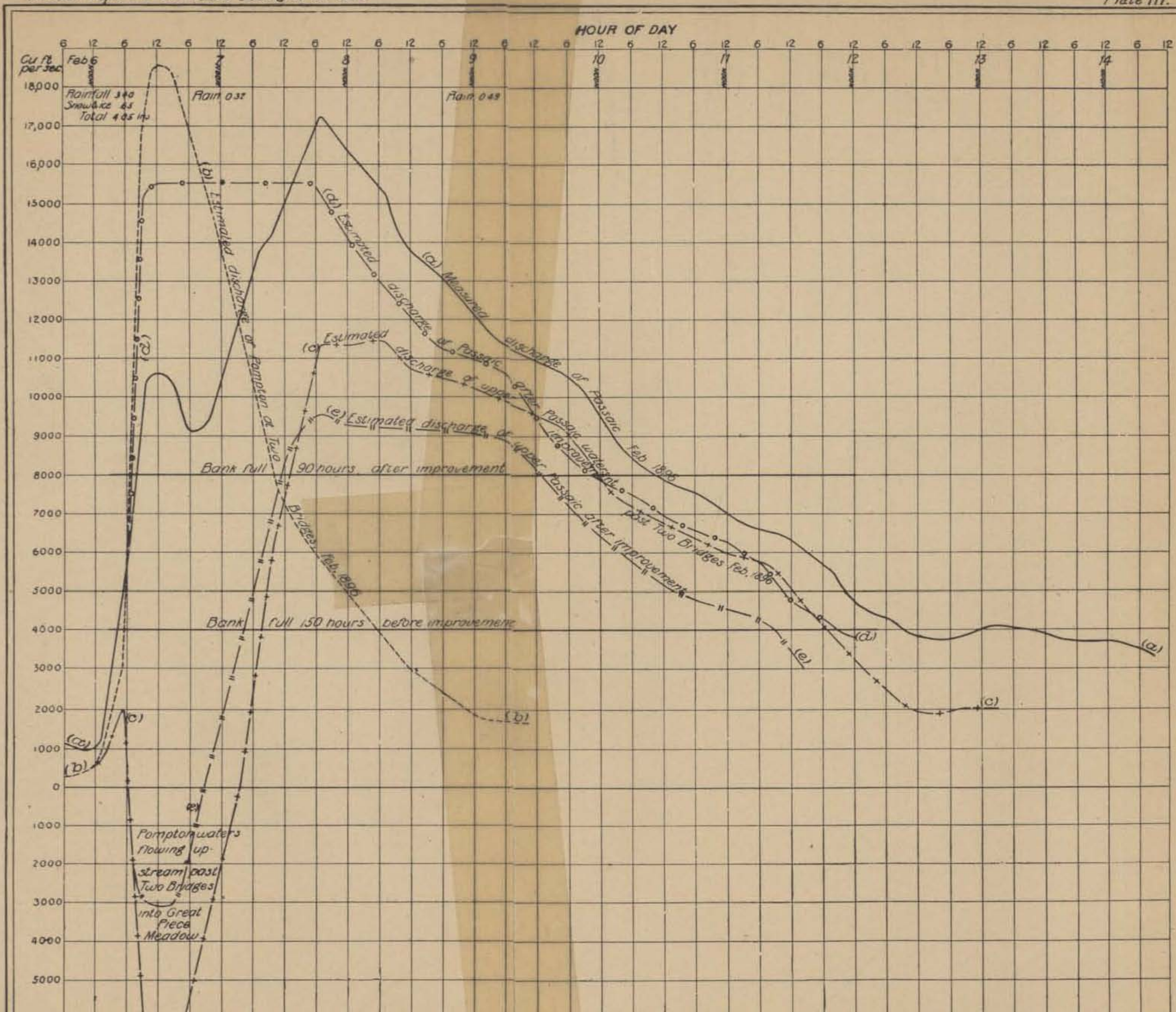


DIAGRAM SHOWING MEASURED FLOW OF PASSAIC RIVER FEB. 6TH, TO MAR. 14TH, 1896
AND THE ESTIMATED FLOW OF ITS TWO TRIBUTARIES AT TWO BRIDGES.
ALSO ESTIMATED FLOW OF THE PASSAIC AFTER COMPLETION OF
PROPOSED DRAINAGE WORKS ABOVE LITTLE FALLS.

amount of water flowing down the main Passaic from Two Bridges, and during that time, consequently, the water was flowing up stream at Two Bridges, into the Great Piece meadow. This curve "c," therefore, indicates graphically the occurrence of this peculiar phenomenon during the flood of 1902.

The remaining lines, marked "d" and "e," on Plate II., indicate the estimated discharge of the river after the completion of certain drainage improvements, to which we will refer later.

Plate III. shows similar data for the flood of February 6th, 1896, the several lines being lettered the same as corresponding lines in Plate II. As this flood presents a marked contrast to that of the present year, it is interesting to compare the two diagrams. The flood of 1896 was the result of a single sudden storm and thaw, which caused sharp rises on all of the branches of the Passaic.

Tracing the flood of 1896 on the diagram, Plate III., it will be noted that after 6 P. M. of the 6th inst. the quantity of water flowing down from the Pompton, at Two Bridges, shown by line "b," exceeded the discharge of the Passaic below Two Bridges, indicated by line "a," and it will be noted that line "a," showing the measured discharge of the Passaic, indicates that at 12, midnight, a maximum was reached, after which the stream fell off for seven hours. This first maximum, which nearly always occurs during great floods on the Lower Passaic, corresponds in time with the height of the flood on the Pompton, and the falling off is due to the fact that immediately after the Pompton begins to subside, the water from the southerly branches does not come down over the flats to Two Bridges rapidly enough to maintain the high rate of flow of the lower river, which has been established by the Pompton. At 7 A. M. of the 7th, equilibrium had been established at Two Bridges, and the waters coming down over the flats, from the southerly branch, again caused the main stream to rise, until it reached its maximum at 7 A. M. of the 8th inst., after which the main stream steadily declined for five days while it was drawing off the accumulated water on the flats above Two Bridges.

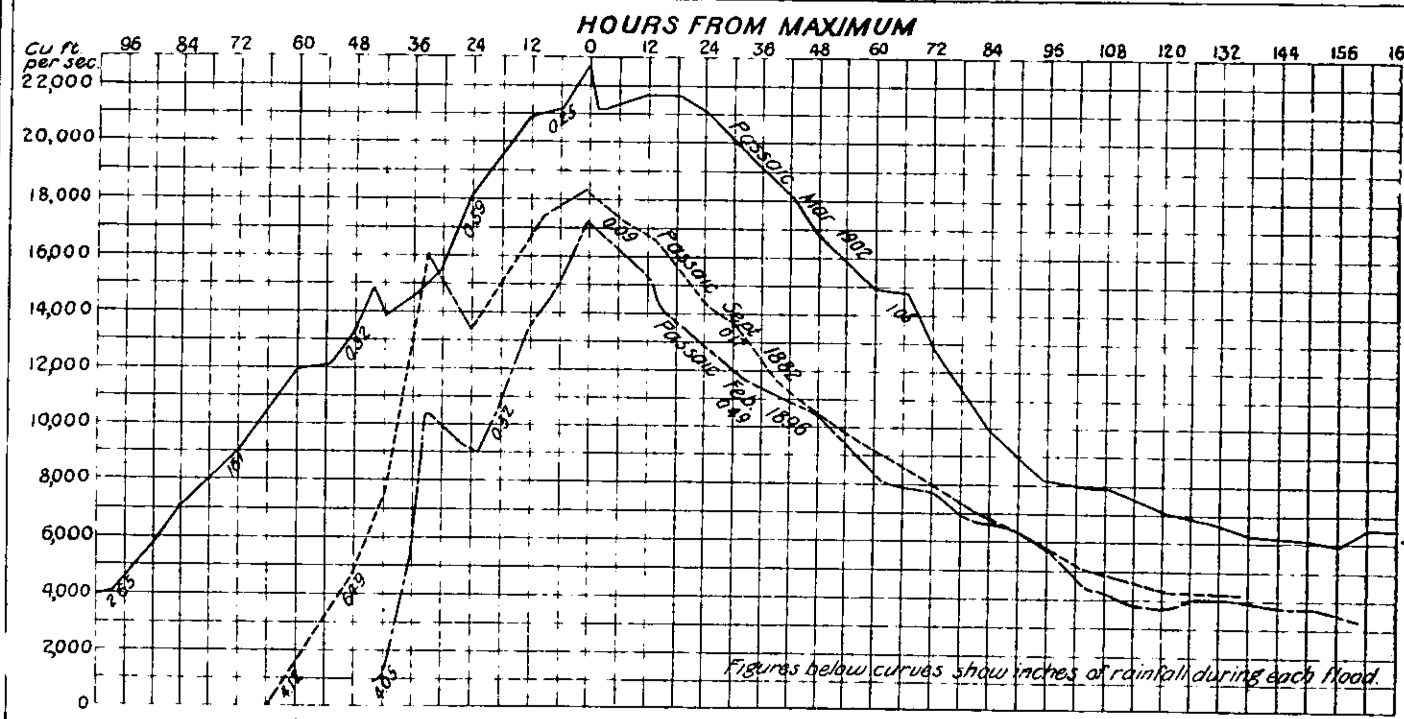
The discharge of the Pompton during this flood was quite accurately ascertained. Taking the difference between the discharge of the Pompton and that of the main Passaic, we are enabled to plot the curve of discharge of the waters of the Upper Passaic, past Two Bridges, as shown by the line "c." It will be noted that after 6 P. M. of the 6th inst. this discharge was a negative quantity until 3:30 P. M. of the 7th inst., during which time the waters of the Pompton were flowing up stream into the Great Piece meadow above Two Bridges, in the same way which was noted in Plate II. for the flood of 1902. This upward flow amounted to nearly 8,000 cubic feet per second at a maximum. As the Pompton declined at 3:30 P. M. of the 7th, a point was reached where the waters again commenced to flow downward from Great Piece meadow, and line "c" shows how these waters came in steadily at an increasing rate until 7 A. M. of the 8th inst., when the downward flow from Great Piece meadow amounted to 11,300 cubic feet per second. For the succeeding 12 hours the inflow and outflow from Great Piece meadow were about equal, after which the river steadily declined.

Lines "d" and "e" of the diagram refer to conditions after the completion of the proposed drainage works, and it is because these two floods are especially instructive as to the effect of these drainage works that we have presented them with such detail.

Plate IV. shows plotted curves indicating the discharge of the Passaic at Dundee during the three floods of 1882, 1896 and 1902. Time is indicated by the vertical lines drawn 6 hours apart, and is reckoned each way from the occurrence of the maximum for each flood, all being plotted with the maxima on the same vertical line.

The horizontal lines show the rate of discharge at any given time, in cubic feet per second.

The relative volume of the several floods is here shown graphically, being indicated by the relative height of the curves, and the figures just below the flood curve indicate the precipitation to which each flood was due. It will be seen that the period from the beginning to the maximum varies from 44 hours, in 1896, to 91 hours, in 1902. The first maximum, due to the inrush of the waters of the Pompton, coincides closely in time reckoned back from the principal maximum in the floods of 1896 and 1882, the interval being about 33 hours, but for the flood of 1902, it is about 45 hours. The parallelism of the curves representing the subsiding floods is quite remarkable, and indi-



COMPARATIVE DIAGRAM FOR PASSAIC FLOODS OF 1902, 1896 AND 1882.

cates that this curve is determined by the emptying of the stored water from the flats in each case.

It is interesting to compare the rainfall and run-off for these three floods, as I have done in the following table:

	Rainfall, inches.	Run-off, inches.	Computed evaporation, inches.	Percolation or loss, inches.
September, 1882	10.87	3.71	2.63	4.53
February, 1896	4.86	3.18	0.58	1.10
March, 1902	6.47	5.35	0.77	0.35

The column headed "Computed Evaporation" represents the evaporation for eight days, during each flood, as determined from the formulæ given in the Report on Water-Supply. Adding together the run-off and the computed evaporation, and deducting their sum from the rainfall, we have for each flood the quantities in the last column, representing the inches of rainfall percolating into the ground, or otherwise unaccounted for. These figures show that the rainfall causing the flood of 1902 is all accounted for excepting about 5 per cent., which is within the limits of error of the measurements, showing that there was practically no percolation, as is to be expected from the fact that this flood followed a rather wet period, and the ground was fully saturated at the beginning. In 1896, the flood followed a dry January, so that there was considerably more percolation. In September, 1882, the flood followed a very dry summer, so that a large percentage of the rain disappeared into the ground.

We may summarize our conclusions as to the Passaic flood of 1902 as follows:

1. Its cause was a heavy, warm rainfall upon accumulated snow and ice, setting suddenly free a large quantity of water. This water was precipitated less suddenly and in a less concentrated manner than in 1896, consequently *none of the branches of the Passaic* reached so high a stage as in 1896, although they remained high longer and discharged a larger total run-off in 1902.

2. *The main stream* reached a maximum of 22,677 cubic feet per second at Dundee, exceeding the flood of 1896 by 30 per cent., and that of 1882 by 24 per cent., and was higher than any other freshet since 1810.

3. The run-off discharged over Dundee dam during eight days amounted to 5.35 inches of rainfall upon the catchment, exceeding by 14 per cent. the volume discharged in 1882, and by 70 per cent. that of 1896.

4. The seeming paradox of a much higher maximum on the main stream than in 1896, while the branches were lower, is due to the modifying action of the flood storage on the flats above Two Bridges, which was sufficient to absorb and equalize a sudden, violent flood of moderate volume like that of 1896, but which was insufficient to similarly modify a flood so long continued, and of such unusual volume, as that of 1902.

5. The run-off was 86 per cent. of the total amount of rain and melted snow which caused the flood, and ordinary evaporation is sufficient to account for the balance, from which we conclude that percolation was very slight, not because the ground was frozen, for it had thawed out during this period, but because it was already saturated with water at the beginning of the storm.

EFFECT OF THE PROPOSED DRAINAGE WORKS ABOVE LITTLE FALLS ON THE HEIGHT OF PASSAIC FLOODS.

Considerable apprehension has been publicly expressed that in case the plans of the Passaic Drainage Commission are carried out at and above Little Falls, the height of such great floods as that of 1902 will be increased to a dangerous extent. This work was begun more than ten years ago, and was suspended for lack of funds in 1893. A number of persons invested in the bonds of the Drainage Commission appointed to carry out this work under the laws of the State, and the work was begun with due notice to all interests. The faith of the State may possibly be in some measure pledged to a reasonable prosecution of this drainage work, which has been beset with difficulties. As a sanitary and economic measure it is important to the future of the central valley, and no obstacle should be placed in its path unless there is a real, substantial foundation for the alarm expressed. This whole question of effect on floods had been carefully considered by several engineers of high standing, before the work was undertaken. In 1893 and 1894, however, the Committee on Drainage of the Board of Managers of the Geological Survey, of which the late Lebbeus B. Ward, C.E., was Chairman, undertook a thorough investigation of all the plans of the Drainage Commission with a view to determining their sufficiency to accomplish the drainage of the flat lands, their effect on the floods of the lower river, their cost, &c. The writer served as consulting engineer to this Committee, and, after making surveys and an examination, reported very fully on these questions to the Committee. The reports were not published, but on the data then obtained the conclusion was reached that the improvements proposed by the Commissioners of Passaic Drainage would not increase, but, on the contrary, would tend to diminish the height of floods. This conclusion has since been fully supported by the additional data obtained during our investigations of the flood of 1896 and 1902, and it seems proper at this time to illustrate from these floods the reasoning on which it is based.

In the agreement made by the Commissioners with the Beattie Manufacturing Co., the following points are fixed as to the extent of the proposed improvements at Beattie's dam and in the channel up to Two Bridges. The dam is to be lowered twenty inches, the channel of the river above the dam to be excavated to a depth of not less than five feet below the lowered dam, and to a width of not less than 200 feet. The bar at Two Bridges is to be excavated to a depth of not less than four feet below the crest of the lowered dam, and to a width of not less than 200 feet below and 100 feet above the mouth of the Pequannock or Pompton river. It is also agreed to remove such obstructions in the Passaic, between said dam and the reef at Two Bridges, as shall insure a clear waterway of a width of not less than 200 feet, and a depth conformable to a grade line which at said dam shall not be less than 5 feet, and at Two Bridges not less than 4 feet below the level of the crest of the lowered dam. Flood gates are also to be inserted at the dam.

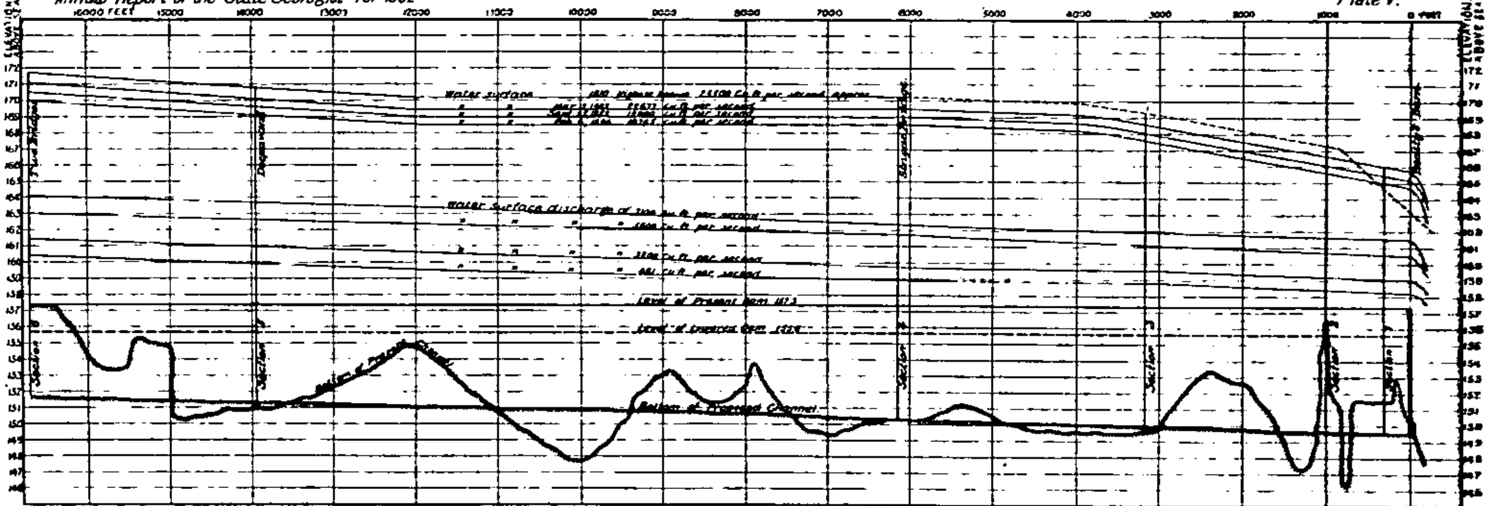
It will be noted that this agreement merely fixes a minimum improvement. The extent of the improvement, however, cannot very much exceed this, owing to the cost. The report of 1894, to the Committee on Drainage, pointed out that the most that could be done, keeping within the limits of a practicable cost, would be to increase the channel width to 250 feet and make its depth 4 feet below the crest of the dam at Two Bridges, and 6 feet below the crest just above the dam, thereby giving a grade or slope to the channel of .12 in 1,000, which we found to be desirable. The side slopes of this rectified channel we made one perpendicular to one and one-half base. There is little doubt that even this scale of improvement very materially exceeds in cost the funds which will ever be available for the work, but for the purpose of this discussion we assume that the work may be completed to this extent in order to show the maximum possible effect on the height of floods. The proposed improvements of the channel are shown in profile on Plate V., and by cross-sections on Plate VI.

The result of such improvements would be a slightly increased cross-section of the river, and what is more important, a lower value of the coefficient of roughness, giving a higher velocity for a given slope. Our surveys and investigations show that the present obstructed channel has a coefficient of roughness, "n" in the Kutter formula, of .032, and it may be safely assumed that the improved channel would reduce this to .025. A lower value than this could not reasonably be expected during flood discharge, owing to the crooked course of the river. A computation based on the data furnished by our surveys shows that the effect of the improvements above indicated would be to reduce the height of the water at Two Bridges, for given stages of the river, to the extent shown in the following table:

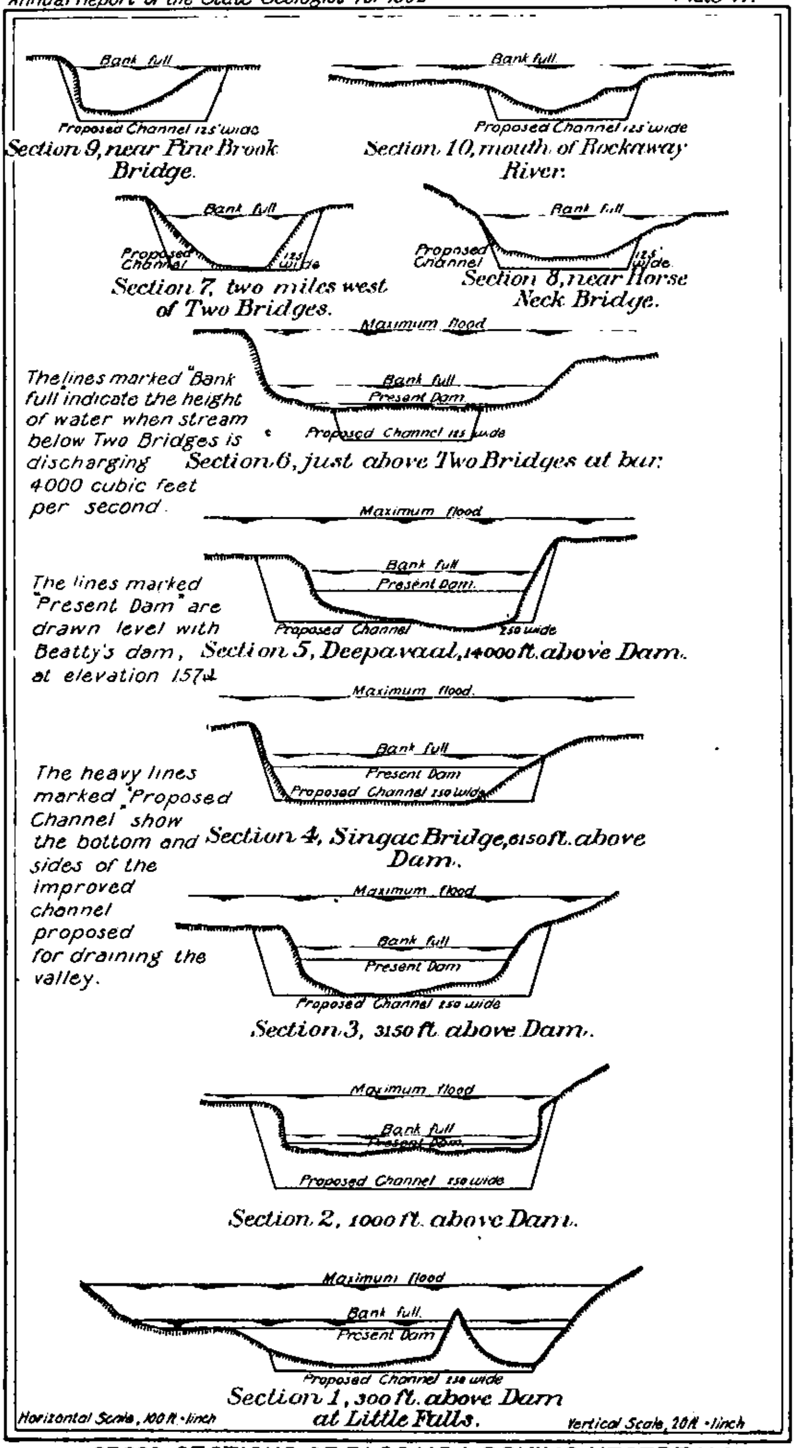
TABLE E.

Stream discharge, in cubic feet, per second.	Elevation of surface of water at Two Bridges.	
	Present channel.	Improved channel.
4,000	161.50	158.75
8,000	164.80	161.50
12,000	167.80	164.90
16,000	169.75	166.75
20,000	170.70	168.70
22,000	171.10	169.50

The present bank-full stage at Two Bridges is 4,000 cubic feet per second, and the table shows that for this discharge the elevation of the water will be reduced by the improvement of the channel from its present height of 161.50 to 158.75, or nearly



PROFILE OF PASSAIC RIVER, TWO BRIDGES TO LITTLE FALLS, SHOWING PRESENT CHANNEL, SLOPE OF WATER AT VARIOUS STAGES AND PROPOSED IMPROVEMENT.



CROSS-SECTIONS OF PASSAIC, LOOKING UPSTREAM

3 feet. With the improved channel, when the water reaches elevation 161.50 it will be discharging 8,000 cubic feet per second, or just double what it now discharges at that height. For all stages of the river up to 16,000 cubic feet per second, the height at Two Bridges would be reduced by the improvement about 3 feet, whereas at the maximum flood discharge the reduction would be only the difference between 171.10 and 169.50, or 1.6 feet.

It may be well to urge in this connection that the real benefits of the proposed drainage improvement do not depend on entirely preventing the overflow of the flat lands in time of great freshets. Such prevention would be not only financially impracticable and dangerous to Paterson, but it may be doubted if it would be entirely desirable for the lands. They are considerably enriched by the sediment deposited at such times. A lowering of the water surface at Two Bridges 3 feet during stages between 3,000 and 8,000 cubic feet per second would be of very much greater benefit than the prevention of overflow by occasional high freshets. Data recorded in the Report on Water-Supply show that the stream is between these stages, on the average, over six weeks of each year, while it exceeds 8,000 cubic feet per second less than four and one-half days each year. For weeks and months these lands are now saturated, not by extreme floods, but when the stream is slightly swollen, or during the tardy discharge of the waters at the end of a freshet, and it is this condition which causes sourness, prevents the raising of useful crops, and produces malarial or miasmatic diseases. The lowering of the river 3 feet during such times would almost entirely remove these serious blights from the Central Passaic Valley.

The profile of the river, Plate V., shows plainly that at the higher flood stages Beattie's dam is not a controlling point. It will be noted that the steep flood slope extends a distance of 4,000 feet above the dam, and the observed height, together with a computation at the cross-sections, made by means of the Kutter formula, show that this control rests with the entire channel, from the dam up to Two Bridges, but is especially affected by the reefs and constricted channel between Singac and the dam. Indeed, for the higher flood stages, Beattie's dam could be entirely removed without causing any appreciable difference in the height of the floods or the maximum discharge of the river.

It was intended by the Drainage Commissioners to put flood-gates in the dam, and one of the questions investigated by the Committee on Drainage of the Geological Survey was the proper size of these gates and their effect. The result of careful computation showed that a capacity of flood-gates in excess of 4,000 cubic feet per second would be useless, and that even with the improved channel the height of floods at Two Bridges would not be affected to any practicable extent by the existence of such gates. At the higher flood stages the discharge would be controlled entirely, even after improvement, by the capacity of the channel from Two Bridges to Little Falls. The effect of such gates, however, would be very beneficial at lower stages of the river, keeping the water level at Two Bridges lower at times when the meadows are now soured by deficient drainage, although not actually submerged by floods.

Since the rate of discharge of the main stream depends entirely upon the height at Two Bridges, whether the channel be improved or not, the question whether the proposed improvement will increase the flood discharge will be determined by ascertaining if, after improvement, the waters at Two Bridges will rise high enough to produce a discharge greater than the present maximum. By referring to Plates II. and III., which show the movement of the floods of 1896 and 1902, the reader will be enabled to follow the reasoning on which we base our conclusions that no such increased flood discharge can occur. We have seen in our analyses of the several floods that the maximum discharge of the Pompton, at Two Bridges, is reached usually about 33 hours earlier than the maximum of the main stream below Two Bridges, and that the channel below Two Bridges is at present insufficient to carry off the Pompton waters as fast as they come down to Two Bridges, so that these waters are held back and driven up stream into Great Piece meadow to augment the flood-waters coming down from the southerly branches. The improved channel, because of its greater capacity, will carry off a larger volume of these Pompton waters during the early hours of the flood, and thereby decrease the accumulation of water on Great Piece meadow, making it impossible for the water to rise as high at Two Bridges after, as it does before improvement.

Take for illustration the flood of 1896, Plate III. On this diagram we have shown by line "d" the curve of estimated discharge of the Passaic after improvement, in accordance with the assumed maximum possible improvement of the river. This curve shows that by midnight of February 7th the improved discharge would have exceeded the discharge of the old channel by 589,000,000 cubic feet, which represents nearly one-third of the entire volume of waters accumulated on the flats during that flood. By midnight of February 6th, the discharge of the old channel had reached 10,600 cubic feet per second. We may assume that after improvement the waters at Two Bridges would reach the same elevation as before, owing to the rapid influx of Pompton water, because at this stage the river would then spread but little beyond its banks. The discharge of the new channel would then be 15,500 cubic feet per second. Now, the measured discharge of the present channel (line "a," Plate III.) shows that when it had reached this stage of 10,600 cubic feet per second, corresponding to elevation 166.9 of water surface at Two Bridges, the main stream began to subside, continuing to do so for seven hours. This subsidence was clearly due to the fact that the waters from the southerly branches could not get down across Great Piece meadow fast enough to maintain a flow of 10,600 cubic feet per second on the lower stream; and consequently, to maintain the improved discharge of 15,500 cubic feet per second, a very considerable improvement of the river channels above Two Bridges will be necessary. We have assumed in our estimates that the improvement will be carried out to a sufficient extent to maintain this discharge. Now, this line "d" shows that by midnight of February 7th the new channel would have discharged 589,000,000 cubic feet more than the old channel. Consequently, as the total accumulation during that flood did not exceed 1,880,000,000 cubic feet, it would have been diminished over 30 per cent. This would have so reduced the height of the water above Two Bridges as to make it impossible for the stream to exceed a maximum of 15,500 cubic feet per second, and we estimate that by 4 A. M. of the 8th it would have begun to decline, as shown by line "d" of Plate III. A reference to line "c," showing the estimated discharge of the Upper Passaic at the same time, indicates that under the new conditions of improved channel these waters will come down a little more promptly at first, as they are not held back to the same extent by the rush of waters from the Pompton, which are now carried down stream, but they reach their maximum discharge at about the same time as before.

The bank-full stage before improvement was 4,000 cubic feet per second, but after improvement this is increased to 8,000 cubic feet per second, so that the period during which the stream is out of its banks at Two Bridges will be reduced for such a flood as this from 150 hours to only 90 hours. Not only will this period of overflow be thus shortened by 60 hours, but the stream will promptly subside still lower and the flats will dry up.

Taking the diagram of the flood of 1902, Plate II., we estimate that the rise of the stream after improvement will not differ materially from that observed for the present channel, as shown by line "a," until the discharge has reached 12,000 cubic feet per second, because during that period the rise of the Passaic was uniform and controlled by the steady swelling of the several branches, which had not yet begun to rise in a violent manner; but from that time forward the discharge by the new channel, shown by line "d," would have been accelerated more rapidly than with the old channel, because of the rapid rise of the Pompton, and, by 6 A. M. of March 1st, we estimate that it would have reached 21,000 cubic feet per second. Continuing at this rate until noon of the 2d of March, it would have disposed of 569,160,000 cubic feet of the waters accumulated on the flats, or about one-third of the whole; consequently, it would have been impossible for the stream to rise at Two Bridges as high as it did before improvement. We estimate that it would not have increased above 21,000 cubic feet per second, but with adequate improvement of the upper channel it would have been maintained at about this rate until 10 A. M. of the 3d, after which it would steadily decline. It will be noted that during this flood, after improvement, the flow of the Pompton is taken care of as fast as it comes down, and that the waters from the southerly branches, or the Upper Passaic, the discharge of which is shown by line "e," will consequently come down more rapidly at the start, but are estimated to reach a maximum discharge almost as great and at about the same time that it actually occurred with the existing channel, as shown by line "c," after which there will be a steady decline as the waters are discharged from the flats.

It may be thought that the fact that the water at Two Bridges would be maintained at a lower level after improvement, should cause a greater slope of the water surface through Great Piece meadow, and consequently an accelerated discharge of the waters of the Upper Passaic; but it will be found that the reduction of depth over the flat, and consequent reduction of the hydraulic mean radius, will effectually prevent any such acceleration, and that consequently a very considerable improvement of the upper channels will be absolutely essential to maintain the flow at even as high a stage as we have estimated.

The result of our earlier studies, confirmed by the history of the floods of 1896 and 1902, indicate clearly, therefore, that any drainage of the wet lands which is financially practicable, or which is necessary and desirable, can be carried out without increasing, but actually decreasing the rate of discharge of floods on the lower river. In order to emphasize the impracticability of any scale of improvement which would imperil the lower river, it may be well to point out that the cost of an improvement on a scale which we have assumed in the above studies would be, for the work below Two Bridges alone, \$192,500, while in order to make this improvement effective above Two Bridges it would be necessary to spend at least enough more to bring the total up to \$250,000, a sum which is far more than the Drainage Commission has ever contemplated. While an improvement to this extent would be entirely safe and desirable, a more moderate scale of works could nevertheless be made effective and useful.

CONTROL OF PASSAIC FLOODS BY STORAGE.

A plan for controlling the floods of the Passaic by storage might be worked out in such a manner that it would at the same time confer other marked benefits, such as, first, converting the unhealthy flat lands of the valley into lakes, thereby eliminating the drainage question entirely; second, providing a larger summer flow of the main stream through Paterson and Newark, and a means of thoroughly flushing the same by artificial freshets.

thereby removing the sewage nuisance; and third, maintaining and improving the valuable water powers at Little Falls, Paterson and Dundee, thereby adding to the prosperity of those places. If large reservoirs should be created, flooding the 20,000 acres of wet lands which it has been proposed to drain, they might be rendered as innocuous as if drained, and the picturesqueness and desirability of the valley greatly enhanced. With properly designed spillways and flood-gates, all floods, even so great a one as that of 1902, could be kept down to the very harmless discharge of 12,000 cubic feet per second, a diminution of over 40 per cent., and such flood control need not cause a variation in the level of such reservoirs exceeding 3 feet. Finally, a draught of 8 feet on such reservoirs would maintain the summer flow of the river, at all times, at 440,000,000 gallons daily, or four times the present summer discharge. Such a flow as this, aided by an occasional flushing by a higher rate of discharge for 24 or 48 hours, would unquestionably greatly mitigate the present evils arising from the discharge of sewage into the lower stream, and might postpone for many years the necessity of expending a large amount of money, estimated at much over $7,000,000, in the construction of the trunk sewer which is now proposed. In proof of this proposition we have only to cite the absence of any serious nuisance during wet seasons, when the stream does not run low.

Such an increase of the summer stage of the river would, moreover, afford additional water-power at Little Falls, Passaic and Dundee, amounting in all to 10,240 gross horse-power day and night, or over 20,000 horse-power for 12 hours daily, which would be worth, at the rates obtained for water-power at those places, $600,000 annually, which, capitalized at 6 per cent., would indicate a value of $10,000,000 for these reservoirs for this purpose alone.

Such a system of reservoirs might be so planned that they would in nowise interfere with, but would add to the value of the stream for municipal water-supply.

To sum up the advantages of such a system of reservoirs, therefore, we should substitute for 20,000 acres of malaria-breeding wet lands an equal area of water-surface, which would greatly enhance the beauty and attractiveness of the Passaic

Valley; we would control such great floods as that of 1902 to an extent which would do away with all damage along the lower stream; we would indefinitely postpone an expenditure of probably not less than $10,000,000 for the construction of a trunk sewer and sewage disposal works on the lower stream; and finally, we would create additional water-power, worth $10,000,000, for use in manufacturing or for other purposes, thereby giving a fresh impetus to the growth and industrial prosperity of Paterson and Passaic and greatly adding to the wealth of the State.

To be sure, the interests affected, public and private, are varied, and the plan could not be made practicable and effective without giving proper consideration to all, but the advantages to all these interests certainly seem to be sufficiently great to make it worth while to give it the careful consideration and to bring about the broad co-operation which will be necessary to its success.

RARITAN CATCHMENT.

At the Delaware and Raritan canal dam, below Bound Brook, it was impossible to compare the flood-heights of 1902 with those of previous freshets, owing to the fact that the dam was washed out early in the year, before the occurrence of this flood, but from notes obtained on the upper stream it is clear that while the total run-off during the flood was very great in volume, the maximum discharge of the stream was less than in 1896. None of the branches of the Raritan reached so high a stage as in 1896, excepting the upper Millstone river. This, being a stream of low maximum, coming from a flat country, appears to agree with other streams of this class, such as the lower Passaic and Pequest, in having reached a greater height than in 1896.

At Rocky Hill the flood is said to have been the highest since 1882. At Griggstown it was 5¼ feet lower than in 1882, but about 5 inches higher than in 1896. At Blackwell's Mills the present flood was 2 feet 2 inches lower than in 1896, and 6 feet 2 inches lower than in 1882.

On the south branch of the Raritan, at South Branch village, the height was the same as in 1896. The following table shows the relative height above sea level of several freshets since 1850, as indicated by flood-marks in the mill at South Branch:

Relative height of floods at South Branch.	Elevations above sea level.
July 29th, 1897	57.23
March 19th, 1896	58.89
August 4th, 1885	58.96
July 23d, 1887	59.43
July 31st, 1889	59.52
February 11th, 1886	59.66
September 23d, 1882	59.96
September 2d, 1850	60.54
July 17th, 1865	60.54
February 6th, 1896	62.27
March 1st, 1902	62.27

The ordinary summer level of the river is at elevation 49.0. It should be noted that the height of the freshet at South Branch does not necessarily represent the relative rate of discharge at the maximum, but may be due to the accumulation of the waters of the north and south branches more rapidly than they can be discharged by the main stream below the confluence.

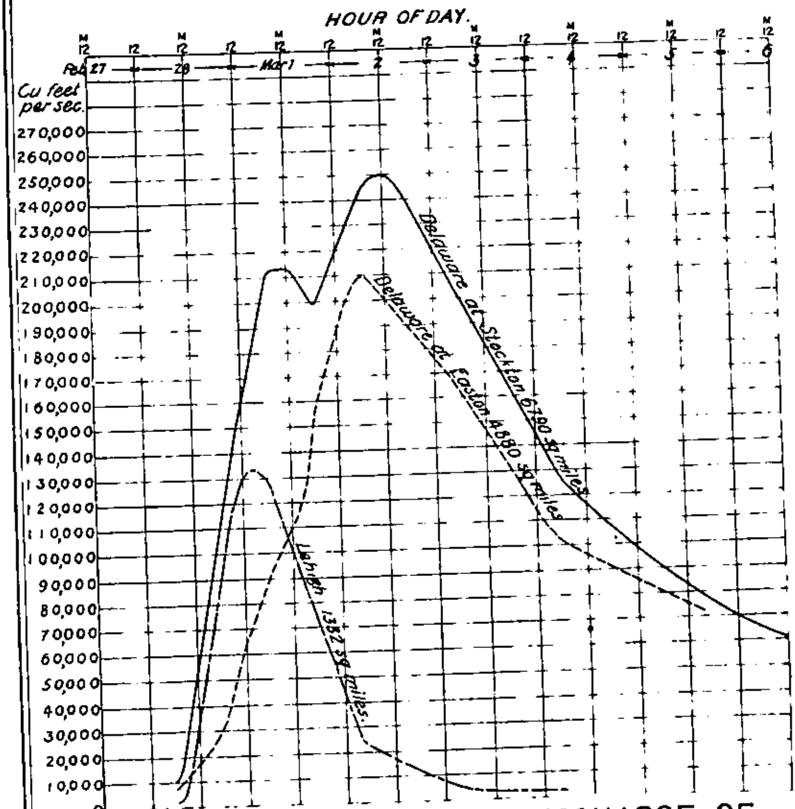
At Neshanic the freshet was 3 feet 2 inches lower than in 1896. Marks in the mill give the following heights of the several floods:

February 6th, 1896	76.79
September 23d, 1882	74.94
1869	74.58
1850	74.04

At High Bridge the water was about 2 feet lower in the dam than in 1896, which makes the rate of discharge not much more than one-half that of 1896.

DELAWARE CATCHMENT.

At Stockton, the Delaware began to rise on February 28th, at 7 A. M., and continued rising quite uniformly until 6:30 A. M. of March 1st, when it reached a discharge of about 213,000 cubic



APPROXIMATE CURVES OF DISCHARGE OF THE DELAWARE RIVER AND BRANCHES FEB. 27TH TO MAR. 6TH 1902.

feet per second. After this it remained nearly stationary for two hours and then subsided gradually until after 6 P. M of the 1st, when it again began to rise, reaching a maximum of about 250,000 cubic feet per second at noon of March 2d, after which it declined quite steadily, until on the evening of the 6th inst. it reached about the same height as when it began to rise. At its highest it was 4 inches lower at Centre Bridge than the flood of 1841, and at Lambertville bridge it was 9 inches lower. On the upper Delaware, at Easton, the freshet of 1862 was also a little higher than that of 1902, but it was two feet lower at Centre Bridge. The height of the flood of 1902 above ordinary low-water at Trenton was 16.6 feet, at Lambertville it was 19.2 feet, at Centre Bridge, or Stockton, 25 feet, at Easton 32 feet, and at Belvidere 22 feet. The accompanying diagram, Plate VII., shows the approximate curves of discharge of the Delaware at Stockton, the Delaware above Easton, and the Lehigh, respectively. It will be seen that the first maximum of the lower Delaware was due to the rush of water from the Lehigh and other lower branches, while the second maximum was caused by the waters of the upper Delaware.

While the Delaware did not reach the height of the great flood of 1841, the volume of the run-off during the flood of the present year was very great, as it was on other streams. An approximate computation shows that during eight days the river discharged at Centre Bridge a total of 77,930,600,000 cubic feet, which equals 4.91 inches of rainfall on the catchment. We have seen that during the same period the Passaic discharged a quantity equal to 5.35 inches of rainfall.

An interesting record of heights of Delaware floods was furnished by Mr. B. M. Youell, who lives near the bridge at Phillipsburg and Easton. This record was kept at Snyder's tannery, at the foot of North Third street, in Easton, from 1777 to 1814. From 1814 to 1841 there is a break, and then, beginning with the great flood of 1841, the record has been kept at Delaware bridge. Combining this record with the records published in the Report on Water-Supply of 1894, we have the following exhibit:

FLOODS ON THE DELAWARE.

Name.	Date.	Height in feet. Lambertville.	Easton.
	October 27th, 1777	....	23.2
	May 9th, 1781	....	25.5
	February 29th, 1783	....	24.4
	March 17th, 1785	....	26.9
Pumpkin Fresh	October 4th-6th, 1786	16	25.2
	1798	less than '86	....
Jefferson Fresh	1801	14	....
	April 1st, 1814	14	24.5
	March, 1832	12	....
	April, 1836	14.5	....
Great Flood	January 8th, 1841	20	32.2
	October 13th, 1843	14	....
	October 13th, 1845	....	22.7
	March 15th-16th, 1846	17.5	27.7
	March 3d, 1857	....	24.3
	July 20th, 1860	....	24.7
June Fresh	June 3d-8th, 1862	18	32.1
October Fresh	October 15th, 1869	....	28.7
	December 11th, 1878	....	28.7
	October 21st, 1879	....	22.8
	March 2d, 1882	....	23.5
	April 14th, 1885	....	21
	February 14th, 1886	....	23.2
	April 1st, 1886	....	21.2
	June 6th, 1886	....	20.2
	September 18th, 1888	....	22.1
	March 12th, 1893	....	21
	April 9th, 1895	....	27.5
	February 6th, 1896	....	28.7*a*
	March 1st, 1896	....	20
	March 2d, 1900	....	18
	March 1st-3d, 1902	19.2	32

a February 6th, 1896, freshet about the same at Belvidere as 1869. Assume same at Easton. No record.

It is interesting to note that the record from 1777 to 1786 shows five freshets exceeding 23 feet rise at Easton during a period of ten years, whereas there is no later period of ten years which shows so many of equal height. Although the record is not complete, this fact appears to throw some doubt on an oft-repeated assertion, to which we have given some credence, viz.: that great floods on the Delaware are more frequent than they were formerly.

The Musconetcong did not reach as great a height as in 1896. At the Warren Paper Mills the maximum was 3,300 cubic feet per second on March 1st, 1902, whereas on February 6th, 1896, it was 4,410 cubic feet per second. At Saxton Falls the maximum was 2,094 cubic feet per second, while in 1896 it was 2,295 cubic feet per second. At Lake Hopatcong the total volume of water discharged into the lake from the catchment amounted to 3.99 inches in 60 hours.

On the Pequest, at Belvidere, a much greater height was reached than during any previous flood during the last 30 years, and the discharge amounted to 2,959 cubic feet per second. This is said to be the highest for this stream since 1862, 1857 having been still higher.

On the Paulinskill, at Paulina, the discharge during the present year amounted to 2,230 cubic feet per second, being much lower than in 1896. Conditions on this stream are somewhat similar to those on the lower Passaic, the streams being bordered by extensive flats.

The Crosswicks creek, near Crosswicks, did not reach an unusual height. In fact, of the Southern New Jersey streams, none equaled the record of 1882. These streams do not usually reach their greatest height during the winter and spring floods, as the snow does not accumulate on the ground to the same extent that it does in Northern New Jersey.

General Conclusions.

Our records of this flood, together with additional data collected for the previous floods, lead to, or confirm the following conclusions:

1. The data do not indicate either increased height or increasing frequency of high freshets during recent years.

2. Since such great floods as those of 1896 and 1902 are largely due to the presence of accumulated ice and snow, and since forests tend to increase such accumulations by shading the earth, such freshets cannot be prevented by forestation. That greater or less amounts of forest cover upon the catchments did

not appreciably affect the flood-discharge of the several streams of similar topography, was shown in the report upon the flood of 1896.

3. Topography and soil, the degree of saturation of the soil, and the rate of precipitation are the principal and probably the only factors in determining the rate of flood-discharge. The rate of precipitation must be determined by including melting snow and ice.

4. The maximum rate of discharge and the volume of run-off have no necessary relation to each other on precipitous catchments, but upon streams bordered by flats they increase or decrease together.

5. Having in the flood of 1882 a summer freshet of a high rate of discharge, with moderate suddenness and ordinary volume of run-off; in the flood of 1896 one of extreme suddenness and high rate of discharge, with small volume of run-off; and in that of 1902 a flood of comparative slowness of rise, with moderate rate of discharge, but very great volume of run-off, our experience embraces a wide range of conditions from which much may be learned as to the regimen of the rivers. The flood-marks of the past indicate that equally great floods have occurred, and on the Passaic even greater ones. There will be no good reasons for surprise if they occur again. Encroachments upon the water-way of the streams, made without regard to these flood-marks, must inevitably result in loss of property if not of life.

REVISION OF RECORDED MAXIMA.

Since the highest floods of which we had record, at the date of preparation of the Report on Water-Supply of 1894, have been exceeded on most of the streams either in 1896 or 1902, it becomes necessary to revise our figures of maximum discharge given on page 103 of that report. This we have done in the following table:

MAXIMUM FLOOD DISCHARGE.

Stream.	Place of observation.	Area of catchment. Square miles.	Maximum discharge in cu. ft.	Maximum discharge in cu. ft. per sq. mile.	Date and remarks.
Ramapo	Pompton	159.5	10,540	66.1	Sept. 22d, 1882.
Wanaque	Pompton	73	7,203	99	Feb. 6th, 1896.
Pequannock	Pompton	48	5,500	115	Feb. 6th, 1896.
Rockaway	Pt. Oram	29.9	1,997	67	Mar. 1st, 1902.
Rockaway	Dover	52.2	2,250	43	Sept., 1882.
Rockaway	Boonton	118.9	5,445	46	Feb. 6th, 1896.
Whippany	Whippany	38	3,200	84	Feb. 6th, 1896.
Pompton		285	......	76	Feb. 6th, 1896.
Passaic	Little Falls	772.9	21,207	27.4	Mar. 2d, 1902.
Passaic	Dundee	822	22,677	27.6	Mar. 2d, 1902.
Passaic	Little Falls	772.9	25,500	33	Estimated for flood of 1810.
Raritan	Bound Brook	879	59,500	68	Feb. 6th, 1896.
Raritan, South Branch	South Branch	276	......	100	Estimated for Feb. 6th, 1896.
Raritan, South Branch	High Bridge	67	7,558	113	Feb. 6th, 1896.
Raritan, North Branch	Milltown	192	......	100	Estimated for Feb. 6th, 1896.
Raritan, North Branch	Pottersville	33	......	80	Estimated for Feb. 6th, 1896.
Dumont's Brook,	North Branch	10.5	......	140	Estimated for Feb. 6th, 1896.
Delaware	Stockton	6,790	254,643	37.5	1841.
Delaware	Easton	4,880	215,000	44.5	Estimated for Mar. 2d, 1902.
Lehigh	Easton	1,332	......	55	Estimated max.
Musconetcong	Riegelsville	132.2	5,692	43	Feb. 6th, 1896.
Musconetcong	Saxton Falls	31	2,295	64	Feb. 6th, 1896.
Lopatcong	Lower Harmony,	3	......	133	
Pequest	Belvidere	158	2,959	18.7	Feb. 6th, 1896.
Pequest	Tranquility	34.8	650	18.7	
Paulinskill	Paulina	126	6,734	54	Feb. 6th, 1896.
Swartswood Lake		16	1,070	65.8	
Great Egg Harbor	May's Landing,	215.8	4,756	22	Maximum.

The above drainage areas are corrected by deducting areas tributary to reservoirs which retained the flood-flow.

There are several formulæ given for computing the maximum discharge of streams, which are used to greater or less extent by engineers. A number of these are quite complicated. It seems desirable to reduce them to the simplest possible terms, from the fact that good judgment and experience in applying such formulæ to a given water-shed are extremely important, and this may be lost sight of in the application of elaborate formulæ. Such a thing as mathematical accuracy is impossible, owing to the infinite variety of conditions presented by different water-sheds. The formula given by Fanning for flood-discharge which may be anticipated upon the average New England and Middle States basins, is as follows: $Q=200\ M^{\frac{5}{6}}$, in which $Q=$ discharge in cubic feet per second, and $M=$area of catchment in square miles. Given a certain type of catchments, this formula seems to express very well the law of variation in discharge due to varying size of catchment. It is a good basic formula, but needs the addition of a coefficient varying with the topography of the catchment. It gives quite accurate results, without correction, for the following New Jersey streams: Dumont's brook, Lopatcong creek, Wanaque, Pompton, Delaware at Stockton, Delaware above Easton, and Lehigh, these water-sheds ranging in size from 3 to 6,790 square miles. For the other streams of which we have record the results of this formula must be multiplied by the following coefficients: 1.25 for the North and South Branches of the Raritan at their confluence; 1.10 for the Pequannock, the main stream of the Raritan and the South Branch above High Bridge; .8 for the Whippany, Ramapo and North Branch of the Raritan above Pottersville; .7 for the Rockaway above Port Oram, Upper Musconetcong and the Paulinskill; .6 for the Rockaway at Boonton, and the Passaic at Little Falls and Dundee; .5 for the Musconetcong at Riegelsville, and the Rockaway at Dover; .3 for the Great Egg Harbor and other streams of Southern New Jersey with flat, sandy water-sheds; .2 for the Pequest. It will be observed that there is a wide range of coefficients. The higher ones apply to streams where there is but a small amount of flat lands along the banks and where the slope of the stream is rapid, while the lower coefficients apply to streams having broad bordering flats and a low rate of slope along the axis of the stream. Rivers like the Raritan, having a number of important branches converging to nearly the same point, have high coefficients as compared with streams having only small branches evenly distributed along its course, such as the Paulinskill or Musconetcong. The choice of a coefficient can be most judiciously made by comparing the catchment with those above named, being sure to select a value high enough.

Artesian Wells.

OUTLINE.

INTRODUCTION.

WELLS IN SOUTHERN NEW JERSEY.

At Waretown.
At Island Beach.
At Barnegat Pier.
At Chadwick.
At Bayhead.
At Farmingdale.
At Sea Girt.
At Key East.
At North Spring Lake.
At Long Branch.
At Deal.
At Matawan.
At Philadelphia, Pa.
At Asyla.
Near Gibbstown.
At Clarksboro.
At Swedesboro.
At Pennsgrove.
At Hammonton.
At Clayville.
At Millville.
At Bivalve.
At Dividing Creek.
At Port Norris.
At Woodbine.
At Cape May.
At Ocean City.
At South Atlantic City.
At Leed's Point.

PART II.

Report on Artesian Wells.

By LEWIS WOOLMAN.

Artesian Wells.

INTRODUCTION.

The writer presents this year data respecting such wells in the Coastal plain portion of New Jersey as time from other important duties has permitted him to collect and study. The records, though not so numerous as in past years, include wells at two localities, viz., Hammonton and Cape May, where accurate and reliable information has been most needed in order to work out satisfactorily the underground structure of Southern New Jersey.

The borings at Hammonton, while they have given much information down to the depth of about 300 feet, were, unfortunately for the geologist, not sufficiently deep to reveal entirely the structural relations of these beds with those of districts both to the east and the west at lower elevations. Had one of the borings at this point been continued from 50 to 150 feet further we should probably have had the data which would permit the construction of a vertical section southwest across the State from the Delaware river to the Atlantic ocean. Such a section would be approximately near the line of the railroads from Philadelphia to Atlantic City. Its construction, however, will have to be deferred for the present.

At Millville, where one deep well and a few shallower ones were reported last year, a considerable number of additional wells, to depths ranging from 66 to 191 feet, have been put down. From these we have gained information as to the probable relations of the upper series of beds here and at other points in Southern New Jersey. The probable correlation of the various beds penetrated is noted in the records of the wells at Millville and Hammonton.

The wells are arranged on the following pages in geographical rather than in geological order.

WELLS IN SOUTHERN NEW JERSEY.

ARTESIAN WELL AT WARETOWN.

Elevation, 8 feet; diameter, 2 inches; depth, 100 feet.
Water rises 12 feet above the surface and overflows 9 gallons per minute.

Drilled and reported by Thomas Roberts.

This well was put down about five years ago. The water-supply was found in a "white gravel" at 100 feet from the surface. Hard clay, light in color, is reported between the depths of 35 and 45 feet, below which were "soft black sands and clays." The location, we are informed, is about three-fourths of a mile west of a well recorded in the Annual Report for 1892, page 293, as having been sunk to the depth of 280 feet. Water was then reported as having been found and passed in the process of drilling at the depths of 70 and of 137 feet.

In the clays procured at that time by the writer from the dump around the mouth of this earlier well, marine diatoms characteristic of the great diatomaceous clay-bed of the Miocene period were found.

WELL AT ISLAND BEACH, SOUTH OF SEASIDE PARK.

Elevation, 10 feet ±; diameter, 2 inches; depth, 73 feet.

Thomas Roberts, who drilled this well, furnishes the following facts respecting it:

Mud bed 8 inches thick between the depths of	12	and	13	feet.
Mud bed 18 inches thick between the depths of	21	"	23	"
Oyster-shell bed 1 foot thick between the depths of	34	"	35	"
Mud bed 18 inches thick between the depths of	35	"	37	"
Reddish sand was entered at			60	"
Coarse white water-bearing sand was found at			73	"

ARTESIAN WELL AT BARNEGAT PIER.

Elevation, 1 foot ±; diameter, 2 inches; depth, 58 feet.
Overflows 1 foot above the surface.

Drilled and reported by Thomas Roberts.

This is a flowing well and was sunk at F. Sutton's on the meadows on the south side of Toms river, near where that stream enters Barnegat bay. The water-horizon opened by this well is thought by the driller, Thomas Roberts, to be the same as that developed by the well at Island Beach at the depth there of 73 feet (see the preceding record).

SHALLOW ARTESIAN WELL AT CHADWICK.

Elevation, 10 feet ±; diameter, 2 inches; depth, 79 feet
Water rises 8 inches above the surface.

Well drilled and data furnished by Thomas Roberts.

This locality is on the strip of beach land between Barnegat bay and the ocean. The well is about six miles north of Seaside Park, and also about six miles northeast from Island Heights, which place and Chadwick are nearly upon the line of strike of the underlying Miocene and Cretaceous formations.

By request of the owner, Theodore W. Stemler, a series of the borings were courteously furnished the Survey by the contractor. From an examination of the same, both microscopically and otherwise, we present the following record:

Soil and meadow muck	surface to 5 feet.
Beach sand somewhat muddy	5 feet to 22 feet.
Sand	22 " " 25 "
Mollusks, viz., *Mytilus edulus* and *Pecten irradians*, at	25 "
Dark sandy clay, contains *sponge spicules* and *diatoms* of species the same as those now living along the coast	25 " " 27 "
Mixture of coarse sand and medium coarse gravel	27 " " 31 "
Clay, dark in color and somewhat micaceous	31 " " 35 "
Mollusks, *i. e. Pecten*, at	35 "
Clay, containing no micro-organisms	35 " " 45 "
Sand	45 " " 46 "
Clay with no micro-organisms	46 " " 54 "
Sand	54 " " 58 "
Gravel mixed with sand	58 " " 60 "
Coarse white gravel	60 " " 68 "
Coarse sand with water	68 " " 74 "
Sandy clay, no micro-organisms	74 " " 79 "

This well, though drilled to the depth of 79 feet, was finished at 74 feet, the depth at which water was found.

ARTESIAN WELL AT BAYHEAD.

Elevation, 10 feet; diameter, 6 inches; depth, 870 feet.
Water overflowed 100 gallons a minute.

Kisner & Bennett, who drilled this well, furnish the above data and the following record which we quote nearly verbatim, inserting, however, two intervals they did not describe, and adding our interpretation of the geology on the right:

Sand surface to	125 feet.		Recent and Miocene.
Rotten stone	125 feet to 200 "	Miocene clay	
Sands same as in Island Heights well	200 " " 225 "		Age?
Marl	225 " " 325 "		Probably Eocene in part.
Very white marl, came out with the (wash-out) water just like milk	325 " " 400 "	Ash marl	Cretaceous.
Greensand marls	400 " " 659 "	Middle and lower marl beds	
Yellowish sand, flowed a nice stream of water, the same as at 400 feet at Asbury Park	659 " " 690 "	Sand at the top of the clay marls. Marlton water-horizon	
Clay marls	690 " " 780 "	Clay marl	
Sands in the middle of the clay marls, *water bearing,*	780 " " 870 "	Cropwell water-horizon	

This is the third well that has been sunk at or near Bayhead. The two former ones had depths of 885 and 813 feet and were recorded in the Annual Report for 1896, pages 151 and 152. This well has a six-inch casing to the depth of 225 feet to the top of the marl series, and was continued below this with a four-and-a-half-inch casing to the depth of 780 feet. The drilling was continued below the casing in water-bearing sands to the total depth named above of 870 feet. The horizon developed is the equivalent of that at about 550 feet at Asbury Park.

THREE SHALLOW ARTESIAN WELLS AT FARMINGDALE.

Depth of one well, about 40 feet below the bottom of the marl-pit. Depths of two wells, 68 and 87 feet below the surface of the ground.

Among our heretofore unpublished data we find notes, made at an interview some years ago with Uriah White, that a well about 40 feet deep had been sunk from a level near the lowest part of the cartway sloping to the bottom of one of the marl-pits at Farmingdale, and that this well passed at its base through 4 or 5 feet of material which he described as "coral."*

Uriah White also at the same time informed us that at a powder factory, about one mile northeast of the above well, there had been sunk two wells to the depth respectively of 68 and 87 feet.

All three of these wells probably reached the same water-horizon.

ARTESIAN WELL AT SEA GIRT.

Elevation, 15 feet: diameter, 6 inches: depth, 750 feet. Water overflows at the surface 28 gallons per minute.

Drilled and data furnished by Kisner & Bennett.

The above well is on the camp-ground at Sea Girt. The water-horizon corresponds with that at the depth of 550 feet at Asbury Park, and is probably the equivalent of that which we have named in Burlington county, the Cropwell water-horizon. It occurs about 175 feet beneath the top of the Clay Marls and is situated well within that formation.

In the Annual Report for 1895, page 75, we recorded a well put down at Sea Girt to the depth of 755 feet, the water-bearing stratum occupying the interval between the depths of 735 and 755 feet. This well doubtless draws from the same water-horizon. For a detailed record of the various beds penetrated the reader is referred to the Annual Report for 1895.

*** These are probably the Bryozoan-bearing beds of the limesand.—H. B. K.**

ARTESIAN WELL AT KEY EAST.

Elevation 10 feet; diameter, 3 inches; depth, 430 feet.

Drilled by Kisner & Bennett, at Hotel Avon.

This well was very briefly reported in the Annual Report for 1885, page 130, but without any stratigraphical notes. More recently the contractors have furnished the following record of beds penetrated:

Sand and coarse gravel	2 feet	=	2 feet.
"Rotten stone," brown.	35 "	=	37 "
Fine light sand	5 "	=	42 "
Whitish clay	10 "	=	52 "
Quicksand, gray	40 "	=	92 "
"Rotten stone," brown	20 "	=	112 "
Coarse sand	8 "	=	120 "
Marl	300 "	=	420 "
"Oyster" shells probably at about 400 or 420 feet.			
Yellowish sand	10 "		430 "

This locality is on the beach north of the mouth of Shark river. On a test this well gave 52 gallons a minute. By comparison of the above record with other wells along the coast and in the interior to the southwest, we conclude that this well reaches the Marlton water-horizon, and corresponds with the depth of 380 feet at Asbury Park.

THREE SHALLOW BORED WELLS AT NORTH SPRING LAKE.

Depth, 47 feet.

These wells were put down in 1891 and are east of the railroad. Kisner & Bennett, who drilled them, furnish the following record:

Soil and white sand, then blue clay to the depth of	27 feet.
Yellow sand	from 27 feet to 47 "

ARTESIAN WELL AT LONG BRANCH.

Elevation, 10 feet; depth, 371 feet.

Among our heretofore unpublished data we find a note that a well was drilled in 1894 by Uriah White, at Long Branch, to the depth of 371 feet. This well is supplied by the same water-horizon as that at the depth of 550 feet at Asbury Park.

ARTESIAN WELL AT DEAL.

Elevation, 20 feet ±; diameter, 6 inches; depth, 112 feet.
Overflows at the surface 300 gallons per minute.

Drilled and reported by Kisner & Bennett.

This well was put down on the shore of Whale Pond brook, about two miles inland from the ocean and near the old town of Deal proper. The location is also about two miles northwest of Deal Beach and one mile west of Elberon.

Kisner & Bennett regard the finding of a strong water-bearing sand in this region, at the comparatively shallow depth of 112 feet, as remarkable. The yield also is certainly phenomenal. This well is probably supplied from the "Yellow Sands" or the underlying limesands.

ARTESIAN WELL AT MATAWAN.

Elevation, 10 feet ±; depth, 205 feet.

Kisner & Bennett report sinking a well for the town supply at Matawan. They found a water-bearing sand between the depths of 185 and 205 feet. This water-horizon occurs well within the Raritan group of sands and clays.

TWO ARTESIAN BORINGS IN PHILADELPHIA AT THE FIDELITY BUILDING, BROAD STREET, NORTH OF ARCH STREET.

Elevation of street, 40 feet.
Well No. 1 Diameter, 8 inches; depth, 46 feet below street level.
Well No. 2 Diameter, 10 inches; depth, 42 feet below street level.

A few years since, at the time of the erection of Fidelity Building, in Philadelphia, two wells were sunk from the floor of the sub-cellar, which floor is about 17 feet below the curb-level of the street. The record for these wells is as follows:

	Thicknesses.	Depths.
Depth to cellar floor	17 feet	= 17 feet.
Coarse loamy sand, reddish in color	12 "	= 29 "
Heavy gravel	16 "	= 45 "
Coarse white sand	1 foot	= 46 "

These wells together yield by pumping 300 gallons per minute. The natural level of the water is said to be about 3 feet below the cellar floor, or about 20 feet below the street level.

ARTESIAN WELL AT ASYLA.

Elevation, 25 feet; total depth, 457 feet; diameter, 8 inches to 190 feet; diameter, 6 inches to 475 feet.
Water rises within 25 feet of the surface.

This well was put down to supply water to the Camden County Asylum.

The sinking of this well was strongly advocated by Charles F. Currie, the Superintendent of the Asylum. With intelligent appreciation of the work of the Survey, he in advance asked our opinion as to the number of water-horizons likely to be met with and their depth. These horizons we predicted and he has since informed us that they were all found, three in number, and near the depths we had named.

The drilling of the same was done by Thomas B. Harper, through whose co-operation with C. F. Currie we have been furnished with a full series of the borings and also with some descriptive data respecting the same. After a careful study of these borings, both macroscopically and microscopically, we present the following record:

Surface soil, contains occasional fragments of limesand rock	Surface to 5 feet.			
Greensand marl with fragments of *Terebratula*, probably *harlani* M. and other shells; also numerous *foraminifera*	5 feet " 10 "	Middle and Lower Marl beds.		Cretaceous.
Similar greensand marl mixed with quartzose sand, contains heavier fragments of shells but no *Terebratula* and very few *foraminifera*	10 " " 20 "			
Nearly pure greensand marl without quartz grains. Contains numerous *foraminifera*	20 " " 40 "			
Sand-mixture of greensand and white quartz grains. Water bearing between 80 and 90 feet. Water rising 14 feet above the surface	40 " " 90 "	Sand. Marlton Water-Horizon.	Clay Marls.	
Black clay marl with greensand	90 " " 140 "	Clay.		
Sand	140 " " 190 "	Sand. Cropwell Water-Horizon.		
Water between 175 and 190 feet that also rose 14 feet above the surface.				
Indurated rock seam 4 feet thick that prevented sinking the 8-inch casing below 190 feet	190 " " 194 "			
Clay marl with greensand*	194 " " 220 "	Clay.		
Sand*	220 " " 312 "	Sand.		
Black clay marl*	312 " " 400 "	Clay.		
Sand	400 " " 437 "	Raritan.		
Coarse gravel with water that supplies the well	437 " " 457 "			

* The combined thickness (206 feet) of these beds is much greater than that of the two lower numbers of the clay marl group, to which they seem to belong. This may be due to the intercalation of a sand bed between the two clay beds, as seems to be the case from the record as given, or it may be that the lower black clay bed of the section belongs in part to the Raritan group.—H. B. K.

We are informed that water rose from below 440 feet to "exactly 25 feet from the surface," that is, to about tide level. This is in keeping with our information elsewhere, as at Camden, Gloucester, &c., where the water from wells sunk to the top of the Raritan beds, and indeed still deeper within them, generally rises only to about the level of tide-water. In this connection, it should be observed that, as stated in the above record, the water from the two higher horizons, viz., the Cropwell and the Marlton water-horizons, rises some 14 feet *above* the surface, or about 40 feet higher than that from the Raritan beds.

C. F. Currie wrote that "with a 4-inch pump worked by the driller's engine the well produced 100 gallons a minute." He also stated that the water is soft and apparently satisfactory, although no analysis had then been made.

NINE ARTESIAN WELLS NEAR GIBBSTOWN AT THE POWDER WORKS OF THE REPAUNO CHEMICAL CO.

Seven wells drilled and reported by Andrew Flemstrom.

Elevation, 5 feet ±; diameter of each well, 3 inches; average depth, 78 feet. Water rises to tide level and varies in height with the rise and fall of the tide. Overflows at the surface with high tides.

Two wells drilled and reported by Haines Bros.

No. 1. Elevation, 5 feet ±; diameter, 3 inches; drilled to 114 feet and finished at 96 feet.

No. 2. Elevation, 5 feet ±; diameter, 6 inches; depth, 90 feet.

Water rises in both wells within about 8 feet of the surface.

The group of seven wells above noted are located on land adjacent to the margin of the marsh between Gibbstown and the Delaware river.

Andrew Flemstrom, who has recently furnished us with the above data, further states that three of these wells were put down in 1899, while the other four were sunk the present year. The group sunk in 1899 are about 1,500 feet west of the group sunk this year. He states that on testing, the three wells of 1899 yielded 300 gallons a minute, while the four of this year yielded 460 gallons a minute. The top of the water-bearing sand was found at the average depth of 75 feet, and the wells were prospected three feet deeper and finished with strainers at the base 6 feet in length. Yellow clay was encountered at the depth of 45 feet, and lignite and "iron," probably pyrite, at about 60 feet. The water is supplied from within the Raritan beds.

Respecting the group of two wells, Haines Bros. state that they were drilled late in 1902, and that the materials penetrated were sands with a few thin interbedded yellow clay seams to the depth of 80 feet—then coarse gravel to the depth of 96 feet, where decomposed micaceous gneiss rock was encountered, which, at the depth of 114 feet, became hard, solid rock.

The wells are at Thompson's Point, on the Delaware river, a mile north of Gibbstown.

ARTESIAN WELL AT CLARKSBORO.

Elevation, 70 feet; diameter, 3 inches; depth, 178 feet. Water rises within 40 feet of the surface.

Well drilled and data furnished by Haines Bros.

This well was drilled for Charles Stewart.

Soil	15 feet	=	15 feet.
Gravel, with water	5 "	=	20 "
Black, loose clayey sand	40 "	=	60 "
Brownish sand, with water	20 "	=	80 "
Marly clays	85 "	=	165 "
White sand, with water	13 "	=	178 "

This well has a strainer at the bottom four feet long. The white sand carrying water is at the top of the Raritan group.

TWO ARTESIAN WELLS AT SWEDESBORO.

Elevation, 10 feet ±; diameter of each, 6 inches; depth of each, 133 feet. Water overflows at the surface about 15 gallons a minute.

Woolwich Water Co. Drilled and data furnished by Haines Bros.

These wells are additional to one put down last year at the same water works plant and to the same depth, and reported in last year's Annual Report, page 78. They pass from the base of the Clay Marls into the Raritan formation and obtain their supply from the water-horizon at the top of the Raritan formation.

The location is upon the east bank of Raccoon creek. The record, with a slight revision, is the same as that published last year. As revised, it is as follows:

Made ground, meadow muck and running sand in succession	0 feet to	10 feet.				Cretaceous.
Black clay marl	10 " "	70 "	Clay Marl.			
Fine black sand	70 " "	85 "	" "			
Dry black clay	85 " "	110 "	" "			
Coarse sand with water	110 " "	133 "	Raritan.			

The water-horizon is also the same as that supplying a well at Mullica Hill 4½ miles eastward, which well has a depth of 265 feet, the elevation of the surface at the two wells being about the same.

TWO SHALLOW WELLS AT PENNSGROVE.

Elevation, 5 feet ±; diameter of each, 3 inches; depth of each, 30 feet. Water rises within 6 feet of the surface.

In the Annual Report for 1901, page 92, there is noted an unsuccessful boring at this locality to the depth of 334 feet, the lower 50 feet being in the micaceous gneiss rock, which is characteristic of Southeastern Pennsylvania, and outcrops in the hills to the westward across the Delaware river. At that time some water, not then noted in our report, was found in a "coarse gravel with large pebbles and bowlders" between the depths of 22 and 30 feet. The two more shallow wells now noted were sunk to this water-horizon, which is practically a surface one. A lead-colored clay was noted in these shallow borings at their base.

FOUR ARTESIAN WELLS AT HAMMONTON.

Elevation, 120 feet.

Well No. 1.—Diameter, 8 inches; depth, 182 feet; length of strainer at the bottom, 20 feet.

Well No. 2.—Diameter, 8 inches; depth, 290 feet; length of strainer at the bottom, 40 feet.

Well No. 3.—Diameter, 6 inches; depth, 305 feet; length of strainer at the bottom, 60 feet.

Well No. 4.—Diameter, 6 inches; depth, 316 feet; length of strainer at the bottom, 60 feet.

Water from Well No. 1 rises within 26 feet of the surface.

Water from Wells Nos. 2, 3 and 4 rises within 30 feet of the surface.

These wells are located adjacent to the Reading Railroad Company's station, and were sunk to supply the town with water. They were drilled by Kisner & Bennett, who kindly furnished full series of the borings and verbally supplied much information. From an examination of these borings, in the light of the information thus supplied, we present the subjoined record. We are also indebted to the borough authorities and to T. Chalkley Hatton, C.E., for courtesies in this connection:

RECORD.

Yellow gravel with iron-stone conglomerate crusts near the top	Surface to	6 feet.	Mainly Sand, 146 feet.
Stiff yellow clay	6 feet "	16 "	
Yellow sand, varying from fine to very coarse (water-bearing, from 25 to 120 feet)	16 "	" 120 "	
Darker yellow clayey sand	120 "	" 146 "	
Stiff black, somewhat sandy clay	146 "	" 156 "	Clays, 16 feet.
Black, very sandy clay	156 "	" 162 "	
Orange yellow sand, with water, supplies Well No. 1	162 "	" 182 "	Sand, 20 feet.
Stiff black clay	182 "	" 196 "	Clays, 48 feet.
Dark, very sandy clay	196 "	" 230 "	
Brownish sand	230 "	" 238 "	Sand, 85 feet.
Sand, very peculiar red (in Well No. 4 only)	238 "	" 244 "	
Coarse, somewhat yellowish sand	244 "	" 315 "	
Water-bearing from 230 to 310 feet, supplies Wells Nos. 2, 3 and 4			
Tenacious, black clay	315 "	" 316 "	Clay, 1 foot, +

After comparing this record with that of a well at Winslow as furnished by Hon. A. K. Hay and recorded by Professor G. H. Cook in Kitchell's* Second Annual Report of the Geological Survey of the State, 1855, page 60, we find a similarity in the succession of the beds down to the depth of 205 feet at Winslow and 230 feet at Hammonton, the elevation of the surface at both localities being the same, or about 120 feet above tide.

* Prof. Cook published a later report of this well in the Geology of New Jersey 1868, in which he described 107 feet of micaceous sand between 150 feet and 257 feet. This interval in his 1855 record was given a threefold subdivision as follows: "Quicksand, 28 feet; black sand, 27 feet; brown sand, 44 feet." It is this earlier record that agrees with this Hammonton section.

In each well at these respective depths the top of a brown sand was entered; this brown sand is stated to be 44 feet thick at Winslow, where, if we may rely upon the record, it rests at the depth of about 248 feet upon a dark-colored or black clay. At Hammonton this brown sand changes to a somewhat yellowish sand towards the base, the two together being 85 feet thick. At the depth of 315 feet these likewise rest upon a black clay, which belongs probably to the same bed as the Winslow clay.

At Hammonton this black clay was not passed through, being penetrated only to the extent of about one foot. At Winslow it was found to be 43 feet thick and to rest at the depth of about 300 feet upon a greensand marl. This depth of 300 feet at Winslow probably indicates the point at which the beds that contain no greensand change to those that do contain it in greater or less quantity. A similar change occurs at Atlantic City, at the depth of 990 feet. A line drawn so as to connect these depths at the two places probably indicates the average dip of the upper part of the greensand beds, *i. e.*, the top probably of the Eocene. The distance between wells at Winslow and Atlantic City is about 31 miles, which, allowing 120 feet for difference in elevation, indicates an average dip along this line of about 26 feet per mile for the base of the Miocene and the top of the Eocene.

The records at Winslow and Hammonton both show that beneath a surface-veneer, not over 15 to 25 feet thick, sands yellowish in color are encountered, and also that the beds are mainly yellow sands, with an exceptional thin black clay-bed to be noted in the next paragraph to about 180 feet. The beds below that depth are none of them yellow.

Two beds of black clay higher than the one already noted as occurring at 248 feet at Winslow and at 315 feet at Hammonton, were found at Hammonton. The higher of these two occupies the interval between 146 and 162 feet, and is a short distance above the base of the yellowish beds of the upper part of the well section, while the lower one occurs between 182 and 230 feet, and marks the division between these upper or yellow beds, and those below that are not yellow.

A similar succession of beds with similar characters has been demonstrated by the wells put down the present year at Millville, as can be seen by comparing this record with the one at Millville, which appears on page 80. At Millville a black clay at 76 to 82 feet, occurs in the yellow beds near their base, while another black clay, the top of which occurs at 92 feet, separates the upper beds which are prevailingly yellowish, from the beds below, which are not at all of that color.

While we do not consider the data so far collected by the Survey as entirely conclusive, we are, nevertheless, inclined to regard the 85 feet of water-bearing sands between 230 and 315 feet, either in their entirety or in part, as probably the equivalent of the great Atlantic City water-horizon that has there a similar thickness and occurs between the depths of 780 and 860 feet. This we have heretofore called the 800-foot Atlantic City water-horizon, from the fact that most of the wells there are prospected to that depth and occasionally somewhat lower.

It will be seen by the record that there are at Hammonton three water-bearing sand and gravel-beds, separated by two clay-beds, while the lowest of the three sand-beds rests upon still another clay-bed. The driller, George B. Kisner, at our request, continued the drilling of the fourth well about one foot into this lowest bed and obtained for the Survey a specimen thereof. From the handling of the drill in the process of the boring he says "the clay in this lowest bed differs from that on the two higher ones in that it is sticky and tenacious, while the two clays above were stiff and sandy." We are inclined to think this lowest bed represents the non-glauconitic Miocene clay, beneath which, elsewhere in the State, there is a sand-bed, sometimes clayey, and always containing more or less true greensand. Careful microscopic examination of all three of these clays fails to reveal any micro-organisms, such as diatoms or foraminifera.

The great 300-foot diatomaceous clay-bed of the Atlantic Coastal plain, which at Atlantic City occupies the interval between the depths of about 400 and 700 feet, is wanting in these borings, although the lower 120 feet of it was met with in well-borings at Egg Harbor, ten miles eastward. The base of this diatom bed probably rises toward tide-level and feathers out midway between these two places, say near DaCosta, and is there overlain by the yellow sands, and perhaps also by the accompanying black clays revealed in the Hammonton borings.

ARTESIAN WELL AT CLAYVILLE, BETWEEN SOUTH VINELAND AND MILLVILLE.

Elevation, about 80 feet; diameter, 1½ inches; depth, 97 feet.

This well was drilled in 1893 by Leach Bros., who then informed us that the materials penetrated were yellowish sands and quicksands all the way down, excepting about 3 feet of dark clay at the depth of about 80 feet. The same firm also put down a second well at the same place, of the exact depth of which we have not been informed, though it was probably finished at about the same depth.

TWENTY ARTESIAN WELLS AT MILLVILLE FOR THE MILLVILLE WATER COMPANY.

Wells.		Diameter.		Depth.		
No.	A,	...	inches,	685	feet	................Test boring.
"	C,	4½	"	204	"	................Water overflows.
"	B,	4½	"	76	"	.... " "
"	D,	4½	"	87	"	.... " "
"	1,	4½	"	172	"	.... " "
"	2,	4½	"	178	"	.... " "
"	3,	4½	"	99	"	.... " "
"	4,	4½	"	126	"	.... " "
"	5,	4½	"	128	"	.... " "
"	6,	4½	"	95	"	.... " "
"	7,	8	"	174	"	.... " "
"	8,	8	"	101	"	.... " "
"	9,	4½	"	103	"	.... " "
"	10,	10	"	69	"	.... " "
"	11,	8	"	80	"	.... " "
"	12,	4½	"	66	"	.... " "
"	13,	6	"	107	"	.... " "
"	14,	4½	"	101	"	.... " "
"	15,	4½	"	191	"	.... " "
"	16,	12	"	74	"	.... " "

Elevation, about 3 feet above high tide.

Water-horizon at 56 feet to 76 feet.
" " 87 " " 135 " } Upper group.

Water from this group rises from 10 to 14 feet above tide.

Water-horizon at 150 feet to 191 feet.
" " 204 " " 212 " } Lower group.

Water from this group rises 22 feet above tide.

The Millville Water Company have for many years supplied that town from the mill-pond there. This water becomes at times slightly colored, and is then what is commonly known as cedar water. In order to ascertain if a perfectly clear and colorless liquid could be had at all times the company, in 1901, put down a test-boring to the depth of 685 feet. This demonstrated the existence of two satisfactory groups of water-horizons above the depth of about 212 feet, but showed no water-supply of satisfactory quality below that depth. They, therefore, sunk the same year three other more shallow wells, two to the upper and one to the lower of these, and the present year they have put down sixteen others, some to the upper and some to the lower water-horizons. The entire series of wells are arranged along the two arms of an L and are 100 feet apart. The deep well (685 feet) and two of the more shallow wells were noted in last year's report, but for completeness of the record at this time we include these (with one other drilled last year) with the wells drilled this year in the above tabulated exhibit. The wells are located on the flats of the Maurice river, just below the breast of the dam and at the head of tide-water, these flats being about three feet above high tide.

We have designated the wells as they have been designated by the water company. Those of last year are lettered, while those of this year are numbered, the numbers being in the regular order of their occurrence along the two arms of the L and not in the order of time in which they were put down.

The 685-feet boring was not used for water-supply. Fourteen of the wells range in depth from 66 to 128 feet, while the remaining five are between 172 and 204 feet deep.

Through the courtesy of the company and of its engineer we have been furnished with a complete series of the borings from one of the deeper wells of the present year, and as this series is more representative than a similar series received last year, we now present a somewhat revised record, which includes, however, information obtained last year as well as this. Below the depth of 185 feet the record is reproduced with some slight amendment from last year.

Yellow sand from near the surface to the depth of......				56	feet.	
Yellow sand and coarse gravel with a good supply of water.....................	56	feet	to	76	"	
Black clay	76	"	"	82	"	
Yellow clay	82	"	"	85	"	
Yellow gravel	85	"	"	92	"	
Black clay	92	"	"	98	"	Probably in part, if not wholly, Miocene.
Alternations of dark clay seams with sands containing water	98	"	"	135	"	
Black clay with casts of marine bivalves....	135	"	"	150	"	
Coarse brownish gray *water-bearing* sands...	150	"	"	185	"	
Clay and coarse gravel, some diatoms and also iron pyrite......................	185	"	"	204	"	Miocene.
Gravel with "a good flow of *water*"........	204	"	"	212	"	
Dark brown clay, no diatoms, but first appearance of fossil mollusks in which the shell itself is preserved...............	212	"	"	221	"	
Gravel, with some shells..................	221	"	"	233	"	
Dark clay, no diatoms.....................	233	"	"	241	"	
Clay, gravel and some shells..............	241	"	"	255	"	
Clay, sandy at the top....................	255	"	"	300	"	
Clay, with comminuted shells..............	300	"	"	310	"	
Dark brown clay...........................	310	"	"	360	"	
Greenish clay	360	"	"	370	"	
Brownish sandy clay.......................	370	"	"	375	"	
						(?)
Greenish mixture of quartz and green sand..	375	"	"	395	"	Upper Layer Upper Marl Bed.
Dark olive-green sandy marl, with abundance of greensand grains..................	395	"	"	438	"	
Similar dark olive-green sandy marl, but somewhat more clayey................	438	"	"	526	"	
Greenish mixture of quartz and greensand, with some fossil shells................	526	"	"	552	"	
						(?)
Greenish sandy clay, with some green sand and some fossil shells.................	552	"	"	630	"	Lower Layers Upper Marl Bed.
Similar greenish sandy clay, but with much more green sand.....................	630	"	"	675	"	
Dark olive-green clayey marl..............	675	"	"	680	"	
Hard rock, slightly calcareous............	680	"	"	685	"	Probably Limesand.

In one of the wells put down this year, at the depth of 135 feet, at the top of the black clay in which occurred casts of marine shells, we found one small flat laminated and indurated pebble about the size and thickness of a dime, which, on being split, unmistakably showed on the inner faces the microscopic remains of marine diatoms. No other diatoms, however, were discovered by a microscopic examination of the clays until the depth of 200 feet was reached.

As already noted, these wells demonstrate the existence at this locality of two groups of water-horizons. The upper of these was developed by the wells whose depths range between 66 and 128 feet. This horizon has also been developed by other wells put down at Millville, at both the upper and the lower glass manufactories of Whitall, Tatum & Co., and also at the plant of the People's Water Company. All of these wells are on the meadows adjacent to the Maurice river, and all of them lower down along the course of that stream. We also regard this horizon as the equivalent of that supplying six wells put down at Vineland for the public water-supply there, which range in depth between 125 and 150 feet, the elevation of the surface being 80 feet. It is also probably the same as that which supplies wells at Bridgeton, whose depths vary from about 80 to 115 feet, according to the elevation. We would further tentatively suggest that it may be the same horizon as has been developed at Hammonton between the depths of 162 feet and 182 feet, and which supplies Well No. 1 at that place (page 74). The lower group of horizons at Millville supplies the wells whose depths range from 172 to 204 feet. We tentatively suggest that this may be the equivalent of the horizon developed by three wells at Hammonton, whose depths range from 290 to 315 feet, the horizon seeming to have a maximum thickness of about 60 to 65 feet. The elevation at Hammonton is about 120 feet above tide.

We are not yet able to correlate with certainty this horizon with any of the water-horizons at Atlantic City, but we suspect that these lower water-bearing sands at Hammonton and at Millville are the same as the great 800-foot Atlantic City water-horizon.

TWO ARTESIAN WELLS AT BIVALVE.

No. 1 sunk for John Yates. Diameter, 2 inches; depth, 198 feet.
No. 2 sunk for Campbell & Bateman. Diameter, 2 inches; depth, 201 feet.
Elevation of each well about 1 foot above ordinary high tide.
Water at 120 to 150 feet that rises 2½ feet above the surface.
Water at 187 to 201 feet that rises from 10 to 11 feet above the surface, varying in height with the tides.

Both wells drilled and reported by George D. Fagan & Son.

These wells were put down in the year 1897 at the oyster-shipping village of Bivalve, which is situated on the marshy flats

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near the mouth of Maurice river and about one mile due south of Port Norris. George D. Fagan & Son have kindly furnished the following record. Except for unimportant differences in the first two members, it will be noticed that the beds penetrated are the same and of the same thickness in each:

	John Yates' No 1 well.	Campbell & Bateman, No. 2 well.	T.tal depths.
Marsh mud	20 feet.	40 feet.	
Beach sand	30 "	10 "	50 feet.
Black quicksand	20 "	20 "	70 "
"Dark mud" or clay	20 "	20 "	90 "
Quicksand	30 "	30 "	120 "
Alternations of clays and sands, water-bearing	30 "	30 "	150 "
Dark stiff hard dry clay	15 "	15 "	165 "
Light-colored quicksand	13 "	13 "	178 "
Rock, described as "porous and like coral"	9 "	9 "	187 "
Coarse white sand, water-bearing	11 "	11 "	198 "
Same continued in Well No. 2		3 "	201 "

The greater depth of marsh deposit in Well No. 2 (40 feet) than in Well No. 1 (20 feet) was because Well No. 2 was nearer the channel of Maurice river than Well No. 1. The depth of 40 feet for these deposits agrees with the maximum depth of the marsh beneath League Island, at the mouth of the Schuylkill (36 feet), and also with the maximum depth of the marsh (40 feet) at the mouth of the Pensauken.

In drilling these wells, water, which, however, was not utilized, was found between the depths of 120 and 150 feet. This water rose about 2½ feet above the surface. This is doubtless the same horizon as that which supplies the well in the town of Port Norris (page 83).

The water from the lower horizon, between the depth of 187 to 201 feet, rises and falls with the tides in the adjacent river. At a height above the surface of 10 or 11 feet the amount of variation is 15 inches.

It is probable also that the water from the higher horizon (viz., 120 to 150 feet), would also have shown a similar tidal variation had a test been made. It will be observed, however, the water from this horizon did not head as high above the surface as does that from the lower one.

ARTESIAN WELL TWO AND ONE-HALF MILES SOUTH OF DIVIDING CREEK.

Sunk for Stultz & Berry.
Elevation, level of tide marsh; diameter, 2 inches; depth, 198 feet.
Water overflows at the surface and rises about 10 feet above it. The quantity overflowing varies from a bucketful, in 17 seconds at high tide, to one in 27 seconds at low tide.

Well drilled and data furnished by George D. Fagan & Son.

This well was put down in 1899. It is located midway in the broad salt marshes that stretch between the town of Dividing Creek and Maurice river cove, Delaware bay. George D. Fagan states that the beds penetrated were the same in succession and in thickness as were found in John Yates' well (No. 1) at Bivalve, four miles to the east. (See preceding record.)

ARTESIAN WELL AT PORT NORRIS.

Sunk for L. M. Lee.
Elevation, 5 feet; diameter, 2 inches; depth, 126 feet.
Water rises 2½ feet above the surface.

Drilled and reported by George D. Fagan & Son.

This well was put down in 1901 and is located on the main street of Port Norris, near the head of a small stream that empties into Maurice river at Bivalve. The water supplying this well is the same as that found below the depth of 120 feet in the two wells at Bivalve (page 81), where, however, it was not utilized. The record furnished by George D. Fagan & Son is as follows:

		Total depths.
Marsh mud	6 feet =	6 feet.
Yellow gravel	9 " =	15 "
Lead-colored quicksand	20 " =	35 "
Coarse dark sand	65 " =	100 "
Alternating layers of clay and sand	15 " =	115 "
Dark quicksand	8 " =	123 "
Same quicksand continued, with water that overflowed	3 " =	126 "

ARTESIAN WELL AT WOODBINE.

Elevation, 40 feet; diameter, 6 inches; depth, 120 feet.
Water rises within 13 feet of the surface.

Drilled and reported by Thomas B. Harper.

This locality is at the head of the Cape May peninsula, and is midway between Great Egg Harbor bay and Maurice river cove.

The well was put down for the Woodbine Machine and Tool Company, at their factory near the railroad station.

From a series of the borings furnished the Survey we are able to present the record below:

Surface beds	0	feet	to	9	feet.
Sand and gravel with fossiliferous (Silurian) pebbles	9	"	"	11	"
Yellow sand	11	"	"	33	"
Orange-colored coarse sand	33	"	"	40	"
Fine sandy clay, yellow	40	"	"	50	"
Coarse clayey sand (deeper yellow)	50	"	"	60	"
Medium yellow sand	60	"	"	70	"
Coarse, sandy clay	70	"	"	90	"
Finer sandy clay	90	"	"	100	"
Darker clayey sand	100	"	"	110	"
Coarse yellow sand water-bearing	110	"	"	120	"

It will be noticed that the beds are prevailingly yellow all the way to the base of the well. Microscopic examination of the clays fails to reveal any micro-organisms.

ARTESIAN WELLS AT CAPE MAY.

Elevation of surface, 10 feet ±.

	Diameters.					
One test well,	10	inches	to	85	feet.	Total depth, 1,313 feet.
	8	"	"	420	"	
	6	"	"	677	"	
	4½	"	"	812	"	
	2½	"	"	1,120	"	
	Prospected with the drill to			1,313	"	

This well was afterward finished to draw water from below the depth of 587 feet. Water rises within about 4 feet of the surface. } Wildwood Water-Horizon.

Six more shallow wells.

No. 1	diameter,	8 inches	depth,	124	feet.	Cape May Water-Horizon.
No. 2	"	8 "	"	125	"	
No. 3	"	8 "	"	122	"	
No. 4	"	8 "	"	125	"	
No. 5	"	8 "	"	121	"	
No. 6	"	8 "	"	120	"	

Water stands at about 14 feet from the surface, with the pumps working.

Early the present year the city authorities of Cape May determined to seek a supply of water by means of deep-well borings, very properly expecting to find at about 900 feet the same water-horizon as occurs at Atlantic City between 780 and 860 feet. This was the more to be expected since its existence beneath the beaches from Harvey Cedars southward to Wildwood had previously been demonstrated.

Accordingly, a contract was made with Thomas B. Harper, who had already successfully put down wells to this horizon at Atlantic City and Ocean City. Contrary to expectation, however, water was not found at 900 feet, although beds somewhat similar to the Atlantic City horizon, both in texture, color and thickness, were found at about the proper stratigraphical position. The first well was therefore continued as a test-boring to the depth of 1,313 feet, but without finding an available supply of water at these depths.

Water-yielding strata were, however, observed between the depths of 90 and 130 feet, of 285 and 300 feet, and of 585 and 600 feet. Consequently this well was finally finished at the depth of 587 feet, so as to draw from the lowest of these three water-horizons, and six other wells were sunk to depths between 120 and 125 feet, to the upper of the three horizons. These more shallow wells are provided with strainers at the base 30 feet long. No well was sunk to, nor test made of the second of these horizons, viz., that at 285 to 300 feet.

Full series of the borings, carefully taken at every ten feet, have been courteously furnished the Survey through the co-operation of Thomas B. Harper, T. Chalkley Hatton, C.E., and of the engineer at the pumping-station, James Rice. We are also indebted to members of the City Council and to Franklin B.

Speace, of the Fire Department, for aid in our investigations and to all of the parties referred to for verbal information from time to time during the progress of the drilling.

From our study of the specimens and of the data thus obtained we are enabled to present the subjoined stratigraphical record:

CAPE MAY.

Sands and gravels of various shades of yellow, gray, buff and orange..........	Surface to 52 feet		Recent.
Black clay, with *recent marine diatoms* and sponge spicules containing also marine mollusks, viz., *Gemma manhattenensis* Prime and *Pholas costata*, Linn	52 feet " 62 "	Diatoms Triceratium favus, &c., and Northern Mollusks.	
Greenish very sandy clay, containing (probably at the base) the following mollusks, viz., *Rangia cuneata*, Gray, and *Pholas costata*, Linn..............	62 " " 85 "	Southern Mollusks.	Age?
Sponge spicules at 72 and 82 feet.			
Heavy whitish gravels, with large pebbles and cobbles, one of the latter showing well marked *Scolithus linearis*, a Cambrian fossil....	85 " " 90 "		
Mixture of coarse gray sand and fine gravel, *water bearing*, supplying the six more shallow wells.............	90 " " 140 "	Cape May Water-Horizon.	
White, very fine clayey sand...............	140 " " 160 "		
Dark gray sand very clayey at the base, no micro organisms in the clay,	160 " " 180 "		
White sand and gravel mixed	180 " " 190 "		
Darker gray, very clayey sand, containing no micro-organisms.............	190 " " 212 "		
A few fragments of much comminuted mollusks apparently bivalves at......	212 "		
Lighter colored sand still quite clayey and without micro organisms..........	212 " " 240 "		
Darker, slightly brownish-gray sands, ranging from fine to coarse, and sometimes quite clayey, no micro-organisms..	240 " " 270 "		
Lignite plentiful at............................	270 "		
Lighter colored gray sand..................	270 " " 285 "		
Coarser gray sand water bearing, but not utilized for water supply	285 " " 300 "	Holly Beach Water-Horizon.	
Brownish yellow sand..	300 " " 310 "		

Stratum	Depth	Division	Bed	Series
Dark clays and sandy clays, without diatoms or other micro-organisms	310 feet to 340 feet.			Miocene.
Comminuted shells at	340 "			
Dark very clayey sands	340 " " 360 "		The Great Diatom Bed, 310 feet thick.	
Coarse sand and fine gravel	360 " " 367 "			
Dark mixture of sand, gravel and clay containing throughout *sponge spicules* and *Miocene marine diatoms*, Miocene mollusks at 370 to 385 feet, at 400 feet and at 420 to 440 feet.	367 " " 440 "	Upper Part of the Great Diatom Clay Bed.		
Sand	440 " " 450 "			
Dark colored, fine, very clayey sand with *sponge spicules* and *diatoms* throughout	450 " " 522 "			
Comminuted shell at 510 to 520 feet.				
Rock seam 11 feet thick, probably indurated sand	522 " " 533 "			
Fine and coarse gray gravels with black barnacles and white molluscan shells	533 " " 560 "			
Some shell at 556 feet.				
Lignite at	560 "			
Grayish coarse sands and fine gravels. Water bearing, supplies the deep well as finally finished. This bed includes a rock seam one foot thick between 584 feet and 585 feet. Lignite occurred at 590 feet	560 " " 600 "	Wildwood Water-Horizon.		
Brown sandy micaceous clay with sponge spicules and abundance of diatoms among the latter notably *Actinocyclus ehrenbergii*, Ralfs	600 " " 660 "	Lower Part of the Great Diatom Bed. Actinocyclus &c.		
Gray sand	660 " " 677 "			
Rock stratum 17 feet thick, probably indurated sand	677 " " 694 "	Non-diatomaceous, — Atlantic City, 69[illegible]–780 feet.		
Gray sand	694 " " 712 "			
Some comminuted shells at 700 feet.				
Rock seam 5 feet thick	712 " " 717 "			
Very fine dark gray sand somewhat clayey	717 " " 775 "			
Still darker (somewhat greenish) and slightly coarser gray sand, with mollusks at 78[illegible] to 79[illegible] feet	775 " " 790 "	Supposed Equivalent of Atlantic City 800-foot Water-Horizon.		
Mixture of coarse gray sand and fine and coarse gravel, with plenty of molluscan fossils	790 " " 812 "			
Rock seam 6 feet thick	812 " " 818 "			
Coarse gray sand and gravel	818 " " 825 "			
Brownish mixture of clay, sand and gravel with comminuted shells, but no micro-organisms	825 " " 849 "			
Rock seam one foot thick	849 " " 850 "			
Very fine clayey sand	850 " " 880 "			
Fine sandy brownish clay, containing throughout an abundance of sponge spicules and a considerable number of diatoms notably among the latter, great numbers of *Actinoptychus heliopelta* Grunow	880 " " 980 "	Lesser Diatom Bed. Actinoptychus heliopelta, &c.	Diatom Bed, 110 feet thick.	
Mixture of diatom clay, sand, gravel and molluscan shells	980 " " 990 "			

	Depth	Beds	Color	Age
The beds above this depth (990 feet) contain no glauconite or greensand, but below this depth all the beds penetrated contain more or less greensand.			Very Dark Green in Color.	Probably in part if not wholly, Eocene.
Dark gray sand somewhat micaceous, contains considerable greensand......	990 feet to 1,020 feet.	Moderately Glauconitic Beds.		
Dark greenish sand, with a large proportion of greensand, with some comminuted small shells at the base,	1,020 " " 1,040 "			
Dark gray sand similar to that at 990 to 1,020 feet, but with more clay in the matrix, also somewhat micaceous..................	1,040 " " 1,070 "			
Dark greensand similar to that at 1,020 to 1,040 feet, but with less comminuted shell..................	1,070 " " 1,080 "			
Greenish-gray, coarse sand and fine gravel mixed, consisting mostly of white quartz grains with a small admixture of greensand..................	1,080 " " 1,090 "	Somewhat Quartzose and slightly Glauconitic Sands.		
Fragments of an echinus at..................	1,090 "			
Similar greenish-gray sand, but without gravel..................	1,090 " " 1,110 "			
Somewhat clayey sand brownish-gray in color the grains mostly quartzose, containing, however, a few greensand grains. "A very little water just trickled over the top of the well at 1,120 feet"..................	1,110 " " 1,130 "			
Clayey sand, consisting largely of greensand..................	1,130 " " 1,140 "			
Black or dark green greensand, somewhat clayey, very little gray sand in this..................	1,140 " " 1,160 "			
Olive green, nearly pure greensand, somewhat clayey..................	1,160 " " 1,280 "	Highly Glauconitic Beds.	Rusty Green	
Some mollusks at..................	1,280 "			
Olive green greensand, still more clayey..................	1,280 " " 1,318 "			
Some *foraminifera* at 1,300 feet..				

A notable feature in the above section is the occurrence of six indurated seams, or rock-beds, two of which are respectively 11 and 17 feet thick. At Atlantic City one such bed, and one only, about one foot thick, usually occurs at the depth of 690 feet. The well records show that these rock-seams increase in number and in thickness southward, until the maximum, both in number and in thickness, has been obtained at Cape May. The two diatomaceous clay-beds in the Miocene are also interesting features.

Correlations.

The following water-horizons are known to exist at Cape May:

Surface wells.—These are dug to depths of 5 to 12 feet.

Driven wells.—These extend to depths of 25 to 30 feet. (Annual Report for 1900, p. 126.)

The Cape May water-horizon.—This horizon occupies the interval between the depths of 87 and 125 feet, and supplies the six shallow wells put down the present year to depths varying from 120 to 125 feet, and also nineteen other wells put down a few years since to depths varying from 79 to 106 feet. (Annual Report for 1900, p. 126.)

The Holly Beach water-horizon.—This occurs between the depths of 285 and 300 feet. It was noticed in drilling the deep well but was not utilized. We predicted this horizon at Cape May in the Annual Report for 1900, page 122, though at a slightly greater depth. It is known also at the following places:

	Interval of depth.	
At Sea Isle City	261 to 278 feet,	not utilized.
At Avalon	270 " 280 "	" "
At Anglesea	284 " 331 "	supplies one well.
At Holly Beach	310 " 326 "	" " "

The Wildwood water-horizon.—This occurs at Cape May, between the depths of 585 and 600 feet and supplies the one deep well at the water-works. It is believed to be the equivalent of that at Bivalve at the depth of 200 feet, at Atlantic City at 525 to 550 feet, and at Wildwood at 620 to 648 feet. It occurs midway in the great 300-foot diatom bed.

All the above horizons are stratigraphically higher than the great 800-foot Atlantic City water-horizon, which seems to be wanting at Cape May, although non-water bearing beds, probably its equivalent stratigraphically, occur between the depths of 775 and 860 feet.

At 1,120 feet.—This scanty water-bearing horizon probably corresponds with that at Wildwood at 1,185 feet.* It may also be the equivalent of that at Atlantic City at 1,135 feet, in the

* Annual Report for 1894, p 178. On page 159 of that report it is wrongly printed as at 1,085 feet.

gas-works well, put down in 1888-89, and still flowing. The supply of water is abundant and the quality satisfactory at Atlantic City. At Wildwood the flow was copious, but the water was salty. Further northward, along the beaches, as well as in the interior of Southern New Jersey, this horizon, if found, may perhaps yield, at least in some localities, water satisfactory both as to quality and quantity.*

Fossils.

At 52 to 62 feet: a cold water form.—The black clay at this horizon contains recent diatoms—one characteristic form, *Triceratium favus,* Ehren, being found in the muds now being deposited along the bays and rivers of the coast. It has also been found in the mud of the Delaware river as far up as Philadelphia. Associated with the black clay are also fragments of *Pholas costata,* Linne, and perfect shells of *Gemma Manhattensis,* Prime, both recent forms, and the latter a minute clam typical of the colder waters of the New England coast, but now not known south of Long Island.

At 85 to 90 feet: a warm water form.—Beneath the black clay—perhaps as much as thirty feet—numerous specimens of a larger clam, *Rangia cuneata,* Gray, were found along with fragments of *Pholas costata.* The former is now abundant in the warmer waters of the Gulf States, and occurs very sparingly on the Atlantic coast, but not, so far as known, north of Cape Hatteras.

At 310 to 360 feet: Miocene Fossils.—Finely comminuted but unrecognizable shells were obtained from this horizon, but from a well at Cape May Point (Annual Report for 1894, p. 158) at the same horizon, Miocene fossils have been found (see above report for list). Microscopic examination failed to reveal any micro-organisms such as diatoms or foraminifera.

Miocene diatom beds at 367 to 677 feet.—This is the great Miocene diatom bed of the coastal plain, frequently referred to in these reports and described fully in the Annual Report for 1894, pp. 165-169. At 625 feet at Atlantic City and at 600-640 feet at Cape May, numerous specimens of the diatom *Actinocyclus ehrenbergii,* Ralfs, have been found.

*** For a resumé of well data at Cape May and vicinity previous to the present time, those especially interested are referred to the Annual Report for 1900, pp. 120-131.**

Comminuted fragments of Miocene molluscan shells also occurred at various depths within this diatom clay-bed. The fossils were usually ground to pieces in the process of drilling, but occasionally unbroken forms were obtained.

At 395 feet.—Good specimens of *Astarte arata*, Conrad, were obtained from this depth.

At 480 to 500 feet.—Considerable numbers of whole shells, together with larger fragments, were obtained from a depth reported as 480 to 500 feet.* Of these Mr. C. W. Johnson has identified the following:

Pecten madisonius, Say.
Nucula proxima, Say.
Corbula inæquale, Say.
Mytilus incrassatus, Conr.
†*Venus mercenaria*, Linn (young).
Ecphora quadricostata, Say.
Crucibulm constrictum, Conr.
Polinices perspectiva, Rogers (young)
Polinices duplicata, Say.
Calyptræa perarmata, Conr.
†*Melanopsis*, —— sp.?
Serpulorbis gramifera, Say.
Turritella cumberlandia, Conr.
Turritella æquistriata, Conr.
Turritella plebeia, Say.
Cancellaria biplicifera, Conr.
Cancellaria, —— sp.?
Nassa bidentata, Emmons.
Nassa peralta, Conr.
Crepidula convexa, Say.
Oliva, —— sp.?
†*Terebra inornata*, Whitf.
†*Terebra*, —— sp.?

* For certain reasons connected with the process employed in drilling this well, it may be that some and perhaps many of the shells thus obtained and marked may have come from a somewhat higher horizon, namely, that of 385 to 390 feet; while others may have been distributed between that depth and the lower depth (480 to 500 feet).

† Forms marked † were also found among the fossils at the Cape May Point well, from a higher horizon (320 to 360 feet). An. Rep. 1894, p. 158.

Astyris communis, Conr.
Calliostoma, —— sp.?
Actæon, —— sp.?
Semele carinata, Conr. (young).
Cerithiopsis bisulcata, Conr.
Mulinea, —— sp.?
Urosalpinx cinerea.
Seila adamsii, H. C. Lea.
Balanus proteus, Conr.

At 575 feet.—C. W. Johnson was able to identify the following fossils from this horizon:

Astarte concentrica, Conr.
Polinices perspectiva, Conr.
Neptunea, —— sp.?
Nucula, —— sp.?
Venus, —— sp.?
Meretrix, —— sp.?
Balanus proteus, Conr.

At Beach Haven and Egg Harbor City this diatom bed rests directly upon the 800-foot Atlantic City water-horizon, while at Smith's Landing, Brigantine, Atlantic City, Ventnor, Longport, Ocean City, Sea Isle City, Avalon and Wildwood there intervene between the diatom bed and the water-yielding sand, non-diatomaceous strata consisting mostly of clay. At Cape May, also, non-diatomaceous clay-beds occur between the great diatom bed, and the non-water yielding sandy strata which are supposed to be the equivalent of the 800-foot Atlantic City water-horizon.

Miocene diatom beds at 880 to 980 feet.—This diatom bed has a thickness of about 100 feet. It is characterized by the occurrence of the diatom *Actinoptychus heliopelta,* Grunow,* which is not found in the great diatom bed above.

This form has been found in clays outcropping at Asbury Park and near Shiloh, N. J., also near Nottingham and Marlboro, Md., and also in borings at Clayton, Del. (100 to 150 feet); Lewes, Del. (910-990 feet); at Crisfield, Md. (790 feet), and at Wildwood, N. J. (1,040 feet). Excepting at Shiloh, these clays rest directly upon beds containing more or less greensand

* This diatom is figured on Plate VI., p. 172, Annual Report for 1894.

marl, while at Shiloh the interval cannot be great. A clay very similar in color and in composition occurs at Atlantic City (860-990 feet), but here we have not been able, after repeated microscopic examinations of specimens from two deep borings, to find any diatoms. This bed is apparently richly diatomaceous to the southwest and very sparingly or at times not at all diatomaceous to the northeast.

At 990 feet.—Here greensand marl becomes a noticeable constituent, there being no greensand grains in any beds higher up. This change has been noted in wells at other localities, as follows:

At Crisfield, Md.	790	feet.
At Lewes, Del.	990	"
At Wildwood	1,104	"
At Atlantic City	990	"
At Island Heights	285	"
At Asbury Park .... about	80	"

This line is supposed to mark the base of the Miocene and the top of the Eocene.

A shell-bed apparently occurs just above this line at Cape May, but the fragmentary condition of the specimens renders identification difficult. Mr. C. W. Johnson has recognized the following:

Mactra, —— sp.?
Odostomia, —— sp.?
Nucula, —— sp.?
Yoldia lævis, Say,
Turbonilla interrupta, Totten (?)
Cadulus thallus, Conr.
Balanus proteus, Conr.

A foraminifera, genus *Biloculina,* was also observed. A similar shell-bed occurs at Wildwood at the corresponding depth (1,100 feet).

At 990 to 1,313 feet.—These greensand beds have been recognized elsewhere as follows:

At Island Heights	between	285	and	504	feet.	
At Atlantic City	"	990	"	1,240	"	
At Millville	"	370	"	552	"	
At Wildwood	"	1,104	"	1,244	"	+
At Lewes, Del.	"	990	"	1,080	"	+

ARTESIAN WELLS AT OCEAN CITY.

One well at water works pumping station, Tenth street, south of the Reading railroad station.

Elevation, 5 feet; diameter, 6 inches; depth, 816 feet.
Water overflows at the surface about 40 gallons a minute, and yields, by pumping, about 175 gallons a minute.

One well at Hotel Aetna.

Elevation, 10 feet; diameter, 4½ inches; depth, 812 feet.
Water did not overflow but yielded, by pumping, about 150 gallons a minute.

Both wells were drilled and reported by Thomas B. Harper.

Both these wells were finished with strainers at the bottom, each 50 feet in length. In drilling the water works well a hard streak, as of stone or rock one foot thick, was encountered at the depth of 632 feet. The great 300-foot diatom clay-bed was passed between the depth of about 390 and 690 feet. A brown sand was also noted in the same boring midway in this diatom bed or between the depth of 550 to 565 feet. The well at the Aetna was on higher ground than the one at the water works, and hence did not overflow. Both wells are supplied from the 800-foot Atlantic City water-horizon.

ARTESIAN WELL AT SOUTH ATLANTIC CITY.

Elevation, 5 feet ±; diameter, 8 inches; depth, 810 feet.
Water overflows 40 gallons per minute.

Drilled and reported by Thomas B. Harper.

This well is situated on the meadows west of the railroad and about three blocks south of the gigantic figure of the elephant that adorns the beach at this locality. The well was finished at the base with a screen fifty feet in length. The water-horizon reached is that which we have designated as the Atlantic City water-horizon, which occurs in a sand-bed some 50 or 60 feet in thickness, the average depth thereto from Atlantic City to Longport is about 800 feet.

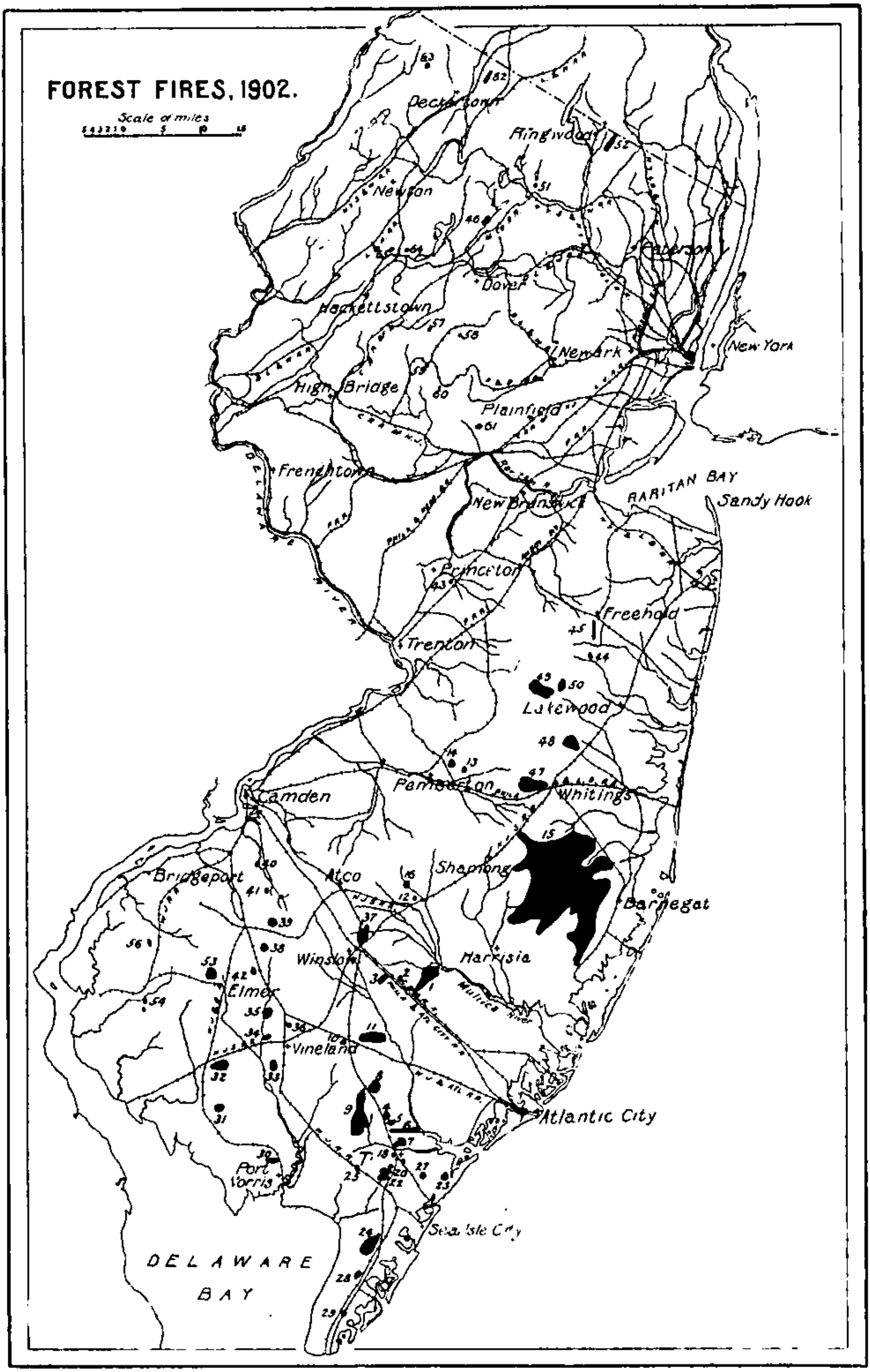
The strata penetrated by this boring agree very closely, depth for depth, with the numerous records that have already been published in past annual reports of wells at Atlantic City, and include, between the depths of about 400 and 700 feet, the great 300-foot Miocene diatom clay-bed.

ARTESIAN WELL AT LEED'S POINT.

Elevation, 55 feet; diameter, 6 inches; depth, 160 feet.
Water rises within 40 feet of the surface.

Drilled and reported by Thomas B. Harper.

This well was put down for Robert Scott. From a specimen of sand received from the bottom of this well we judge that the water comes from a brownish sand-bed that overlies the great diatom clay-bed. This brown sand occurs in the Atlantic City wells between the depths of 270 and 390 feet. This well is located about nine miles nearly due north of the wells at Atlantic City, while the wells at both localities are nearly upon longitude line 74° 26′. The one, however, at Leed's Point is about five miles farther back on the dip of the beds than those at Atlantic City.



MAP SHOWING THE EXTENT OF THE FOREST FIRES IN NEW JERSEY DURING 1902.

PART III.

Forest Fires in New Jersey During 1902.

Notes on Basket-Willow Culture.

By F. R. MEIER.

Forest Fires in New Jersey During 1902.

BY F. R. MEIER.

During the past season fires have continued to devastate large areas of timber-land, particularly in Atlantic, Burlington, Cape May and Ocean counties. The northern half of the State, however, has not escaped, as is shown by the record given below of fires in Morris, Passaic, Somerset and Sussex counties.

In order to determine accurately the areas traversed by these fires and the damage done, each burned tract was visited and the character of the timber examined. It is believed that the damage has been conservatively estimated, and that the figures are too low rather than too high. For convenience the list is arranged by counties.

ATLANTIC COUNTY.

1. April 25th, 1902. Fire started in the village of Elwood from a burning house, and burned on both sides of the road from Elwood to Pleasant Mills, over a section four miles long, one and one-half miles wide; comprising 3,500 acres, covered with young timber from ten to thirty years old, some of which was particularly good. The fire was very severe, killing all trees, pitch pine, yellow pine, white, red and black oak, cedar and chestnut, including two chestnut plantations. Several buildings and one church were also destroyed, which are not included in the estimated damages. Fire lasted eight hours; average loss, $2 per acre; total loss, $7,000.

2. June 6th, 1902. A fire occurred along the railroad tracks between Elwood and Hammonton, caused by a locomotive. It covered twenty-seven acres of young pitch pine twenty years old, which was partly burned. Average loss, $4 per acre; total, $108.

3. April, 1902. Southwest of DaCosta, a farmer burning brush, started a fire which swept over eighty acres of pine and oak timber ripe for cordwood, which was partly killed, partly injured. Average loss, $4.50 per acre; total loss, $360.

4, 5, 6, 7. April 25th or 27th, 1902. At the so-called Lee Crossing, south of Ridley station, four fires were set by locomotives. They burned from the railroad to the Great Egg Harbor river. The burned areas comprised (*a*) 200 acres of oak and pine fifteen years old, killed; average loss, $3 per acre; total loss, $600; (*b*) 160 acres oak and pine ten years old, injured; average loss, $2 per acre; total loss, $320; (*c*) 1,200 acres oak and pine, ten to forty years old, killed; average loss, $5 per acre; total loss, $6,000; (*d*) 150 acres oak and pine twenty years old, killed; average loss, $4 per acre; total, $600.

8. May 2d, 1902. Near Millway, a fire caused by a locomotive swept over 150 acres of oak and pine, twenty years old, and of good growth, which was entirely killed. Average loss, $4 per acre; total, $600.

9. April 26th, 1902. One mile west of Millway, a locomotive started a fire which burned 5,000 acres of pitch pine, white oak, black and red oak, and two small cedar swamps of four and five acres, respectively. Eight hundred acres were of fine oak and pine, thirty years old, the rest from ten to fifteen years old. Average loss, $3 per acre; total, $15,000.

10. May, 1902. One mile west of Richland, a fire was caused by Italians clearing land. Fifty acres of fine oak and pine timber, forty years old, were burned, causing an average loss of $6 per acre; total, $300.

11. May, 1902. Between Richland and Weymouth, another fire was also started by Italians clearing land. It injured, but did not kill, 900 acres of pine, ten to thirty years old. Average loss, $1.75 per acre; total, $1,575.

BURLINGTON COUNTY.

12. May, 1902. Near Atsion, eight acres of pine, eighteen years old, were killed by a fire started by a locomotive. Average loss, $5 per acre; total, $40.

13, 14. May, 1902. At Brown's Mills, charcoal-burners set two fires which swept over 100 acres, but owing to repeated burnings of this tract the damage was inconsiderable.

15. May 9th, 1902. Locomotive sparks started a fire near Woodmansie, which burned 75,000 acres, one-third in Burlington, two-thirds in Ocean county. This fire swept in a southeasterly direction to the coast, lasting three days on one wing, and ten days on the other, and burning over a tract twenty miles long and from one to eight miles wide. The little village of Jungs Neck was in great danger of being destroyed. The fire was finally extinguished by rain, after burning some fine pine and cedar timber. No effort was made to extinguish this fire except where it threatened the village of Jungs Neck. Average loss, $1 per acre; total, $75,000.

16. July, 1902. Three miles north of Atsion, smokers started fires which burned twenty acres of pine, eighteen years old. The timber was killed. Average loss, $3 per acre; total, $60.

CAPE MAY COUNTY.

17. May 21st. Two miles south of Tuckahoe, a fire started by a locomotive entirely killed thirty acres of oak and pine of poor quality, thirty years old. Average loss, $2 per acre; total, $60. It also burned fifty-three acres of seasoned cordwood worth $2 per cord, $106.

18. June 5th, 1902. In Tuckahoe, ten cords of oak cordwood, worth $2 per cord, were burned by a fire started by a locomotive.

19. August 20th, 1902. East of Steelmantown, a locomotive set fire to eleven cords of seasoned oak cordwood valued at $2 per cord; total, $22.

20. August 20th, 1902. East of Steelmantown, a locomotive set fire to 500 acres of oak and pine timber of fine quality, fifteen years old. It was partly killed and partly stunted. Average loss, $3 per acre; total, $1,500.

21. August 21st, 1902. Another fire, also east of Steelmantown, due to a locomotive, burned 150 acres of oak and pine of fine quality, fifteen years old. The timber was killed. Average loss, $5 per acre; total, $750.

22. August 21st, 1902. The same day a second fire, east of Steelmantown, also due to a locomotive, burned 250 acres of second-class oak timber, fifteen years old. Timber was injured, but not killed. Average loss, $2 per acre; total, $500.

23. May 16th, 1902. At Palermo, a fire, cause unknown, traversed sixty-five acres of oak and some pine of poor quality, five to twenty years old. Timber was partly killed. Average loss, $0.50 per acre; total, $32.

24. May, 1902. A fire, due to a locomotive, swept from Dennisville to Goshen, burning 800 acres of scattered pine with some good oaks, from ten to twenty-five years old. It was finally extinguished by an organized party of eight men, employed by the owner of the property. Average loss, $1.50 per acre; total, $1,200.

25. August 12th, 1902. At Woodbine, a fire, set by a locomotive, was extinguished by section men and citizens of Woodbine before damage was done.

26. August 19th, 1902. A second fire at Woodbine, a week later, also due to a locomotive, was extinguished by section men and citizens of Woodbine, without damage. These two instances show what can be accomplished by prompt action.

27. August, 1902. At Petersburg, a farmer, in clearing land, caused a fire which burned ninety acres of poor woodland. Owing to repeated burning the tract was of little value. Average loss, $0.50 per acre; total, $45.

28. May, 1902. Near Anglesea Junction, an incendiary fire destroyed forty-five acres of fine pine and oak, of forty years' growth. Average loss, $10 per acre; total, $450.

29. April, 1902. Near Rio Grande, fire set by smokers burned and killed twenty acres of pine sprouts, twelve years old. Average loss, $1 per acre; total, $20.

CUMBERLAND COUNTY.

30. May, 1902. About two and one-half miles east of Dividing Creek, locomotive sparks set fire to 125 acres, mainly of oak, with some pine, ten to twenty years old. Trees were injured and some killed. Average loss, $1.75 per acre; total, $218.

31. May 8th. At Fairton, a farmer burning brush burned and killed 300 acres of very thrifty oak and pine timber, fifteen years old. Average loss, $6 per acre; total, $1,800.

32. April, 1902. A mile east of Bridgeton, a farmer burned off a small lot on a windy day. The fire spread to 800 acres of excellent oak and pine timber, thirty years old, which was killed for the greater part. Average loss, $20 per acre; total, $16,000.

33, 34, 35, 36. April, 1902. Four fires in the interior of Landis township were all caused by men clearing land. According to information from reliable persons in Vineland, 2,000 acres of young pines and oak were destroyed. The damage is estimated at an average of $5 per acre; total, $10,000.

CAMDEN COUNTY.

37. April, 1902. Near Winslow Junction, locomotive sparks or coals set fire to 400 acres of pine timber, fifty years old. Average loss, $15 per acre; total, $6,000.

GLOUCESTER COUNTY.

38. April, 1902. One mile east of Clayton, a fire was started by burning brush. It burned and killed 275 acres of thrifty oak, with some scattered pine, nineteen years' growth. Average loss, $3 per acre; total, $825.

39. May, 1902. Near Downer, at Willow Grove, from burning brush, a fire spread to 400 acres of oak timber, thirty-five years old, which was killed. Average loss, $3.50 per acre; total, $1,400.

40. May, 1902. One mile southwest of Almonesson, on the "parsonage grounds," burning brush set fire to seventy-five acres, chiefly of thrifty oak, forty years old; mostly killed. Average loss, $9 per acre; total, $676.

41. May, 1902. Near Prosser's Mills, at "New Brooklyn," fire from burning brush, swept over sixty acres, chiefly of thrifty oak, forty years old. The timber was mostly killed. Average loss, $8 per acre; total, $480.

42. June, 1902. A little east of Franklinville, a fire set by a feeble-minded person, who desired to see the woods burn, devastated 120 acres of oak and some chestnut and scattered pine. This tract had been protected from fire for a long period and was from twenty to forty years old. The greater part was killed. Average loss, $7 per acre; total, $840.

MERCER COUNTY.

43. June, 1902. At Princeton Junction, burning brush set fire to fifteen acres of oak of thirty years' growth. The trees were killed. Average loss, $10 per acre; total, $150.

MONMOUTH COUNTY.

44. April, 1902. A fire started from some unknown cause near Prospect, near the road leading from Smithwood to Lakewood. It burned and killed 220 acres of oak with some pine. Average loss, $5 per acre; total, $1,100.

45. May, 1902. Near Freehold, a fire, cause unknown, swept over 400 acres of fine chestnut timber, forty years old. Average loss, $12 per acre; total, $4,800.

MORRIS COUNTY.

46. June, 1902. West of Denmark, hunters set fire to 350 acres of oak and chestnut on Green Pond mountain. The timber was thirty years old, and was killed in part. Average loss, $2 per acre; total, $700.

OCEAN COUNTY.*

47. April, 1902. Near Whitings, a fire, due to locomotive sparks, burned 1,000 acres of pine, partly seedlings, thirty-five years old, of good quality, partly scattered pine of poorer quality,

* See, also, record for Burlington county.

of five to twenty-five years' growth. The seedlings were killed, the scattered pine more or less injured. Average loss, $2 per acre; total, $2,000.

48. May 8th, 1902. Near Manchester, fire was set by smokers to 300 acres of pine of poor quality, mostly sprouts, ten to forty years old. The trees were killed. Average loss, $2 per acre; total, $600.

49. May, 1902. Northwest of Cassville, a fire was set maliciously to destroy cordwood. It burned 1,280 acres of poor quality of pine timber, fifteen years old, and 350 cords of pine cordwood. Loss on cordwood, $1.75 per cord. Average loss to standing pine, $0.75 per acre; total, $1,572.

50. May, 1902. Northeast of Cassville charcoal burners set fire to 500 acres of poor, scruby pine of little value. Average loss, $0.25 per acre; total, $125.

PASSAIC COUNTY.

51. April, 1902. At Charlotteburg, fire, set by smokers, burned and killed twenty-five acres of oak and chestnut, forty years old. Average loss, $4 per acre; total, $100.

52. April, 1902. Near Negro pond, a fire, set by hunters, burned 1,100 acres of oak and chestnut, forty to fifty years old. The trees were partly killed and partly very badly injured. Average loss, $4 per acre; total, $4,400.

SALEM COUNTY.

53. May, 1902. Near Elmer, a fire, set by burning brush, burned and killed 400 acres of oak and chestnut, thirty years old, and 120 cords of wood worth $2 per cord. The damage to the standing timber is estimated at $5 per acre; total, $2,240.

54, 55. May, 1902. Near Alloway, two small fires were caused by burning brush, but were extinguished without damage.

56. May, 1902. One-half mile west of Woodstown, a fire was set, probably by a tramp. Eighty acres of oak sprouts were badly damaged. Average loss, $3 per acre; total loss, $240.

SOMERSET COUNTY.

57, 58, 59, 60. Four small fires were started by burning brush at Far Hills, Mendham and Chester, but were observed in time and extinguished before any damage was done.

61. May, 1902. A fire at Martinsville, cause unknown, burned 100 acres of oak and chestnut timber, twenty to forty years' growth, which was partly injured. Average loss, $4 per acre; total, $400.

SUSSEX COUNTY.

62. July, 1902. Hunters started a fire near Milton which burned and killed 100 acres of oak and chestnut sprouts of ten years' growth. Average loss, $3 per acre; total, $300.

63, 64, 65. July, 1902. A fire near Colesville, caused by hunters, burned and killed thirty acres of oak and chestnut sprouts ten years' growth. Average loss, $3 per acre; total, $90. Hunters also caused two fires near Waterloo, but these were extinguished in time with very little damage.

SUMMARY.

The above statement shows that between April and September sixty-five fires occurred in fourteen counties; that 98,850 acres of timber land were burned over, with a total damage conservatively estimated at $168,323. With very few exceptions, which have been noted, absolutely no attempts were made to extinguish these fires, which were allowed to burn themselves out. The causes were as follows: Set by locomotives, 21; farmers burning brush and clearing land, 22; hunters, 6; smokers, 4; unknown, 4; charcoal burners, 3; incendiary, 2; tramp, 1; feeble-minded person, 1; accidental, 1.

A summary by counties is as follows:

Atlantic	11	fires,	11,417	acres	burned,	damage,	$32,463 00
Burlington	5	"	25,128	"	"	"	25,100 00
Cape May	13	"	1,950	"	"	"	4,705 00
Cumberland	7	"	3,225	"	"	"	28,018 00
Camden	1	"	400	"	"	"	6,000 00
Gloucester	5	"	830	"	"	"	4,220 00
Mercer	1	"	15	"	"	"	150 00
Monmouth	2	"	620	"	"	"	5,900 00
Ocean	5	"	53,080	"	"	"	54,297 00
Passaic	2	"	1,125	"	"	"	4,500 00
Morris	1	"	350	"	"	"	700 00
Salem	4	"	480	"	"	"	2,480 00
Somerset	5	"	100	"	"	"	400 00
Sussex	4	"	130	"	"	"	390 00
	66*		98,850				$169,323 00

* One fire counted in both Burlington and Ocean counties.

Notes on Basket-Willow Culture.

BY F.. R. MEIER.

The cultivation of the basket willow has received most attention in Germany, France, Italy, Belgium and South Russia, but up to the present time little attention has been given it in this country, and by far the largest part of the willows used in basket manufacture is imported. In France and Germany, where the cultivation of the willow has reached the greatest perfection, it has proved so profitable that farmers do not hesitate to plant the best of their wheat land in willows. Experiments have fully demonstrated that basket willows, of the same kind and quality as the imported varieties, can be grown and marketed in this country at a great profit. There are many thousands of acres in the State, particularly in the southern portion, unfit for agriculture on which the basket willow could be grown at a handsome profit.

The Soil.—The most suitable soil for its growth is a deep, rich moist, alluvial soil, but any good clayey soil will do well, if it is sufficiently moist. Sand and gravel soils are unsuitable, however. A moist soil is essential, but they will not thrive in stagnant water. Before planting, the soil should be thoroughly worked or plowed to a depth of fourteen inches or more. This is best done in the fall, the planting being done in either the fall or early spring. The more thoroughly this preliminary working is done, the better the growth after planting.

Kinds of Willow.—In order to secure good results, only the right sort of willow should be planted. This is of more importance since there are many varieties not all equally good for basket work. A good basket willow must be a quick grower, tough and pliable, and must have no side branches. The following varieties are recommended: *Salix amygdalina, Salix purpurea, Salix viminalis.* All of these are in demand by basket-makers, as they are all pliable, tough and durable.

The *Salix amygdalina* is a quick grower with heavy, strong yearly roots. The color, when peeled, is very white (a good quality). The wood is in demand for heavy and very fine basket work.

The *Salix purpurea* has many thin, long, pliable shoots, without side branches and is used for fine basket work only.

The *Salix viminalis* is a good grower, even on the poorest soil, but it is not wanted for fine basket work on account of the great thickness of the shoots. It is used for rough basket work and is seldom peeled. These three varieties will satisfy the demand of any basket-maker.

Planting.—Planting is done in the fall or early spring, of cuttings taken from willows of one or two years' growth. The cuttings should each be twelve inches long and the whole should be planted vertically, the top even with the surface.

While there is some difference of opinion as to distance between rows, in general the best results are secured by close planting. The rows should be seventeen inches apart and the distance of plants in the rows five inches. Since basket willows do not reach tree-size, and the stump in the ground hardly reaches the thickness of a man's arm, this distance leaves sufficient space between the rows. In some cases they are set as close as fourteen inches, or as far apart as twenty-four. If planted as recommended above, 73,000 plants per acre are required.

While it is best to make the cuttings only a few days before planting, yet where this is not practicable, the cuttings may be kept for a month or more without harm to the sprouting power of the plant, provided they are kept under shelter and protected from excessive dryness or moisture. *They should not be kept in water.*

Cultivation.—After planting, the rows should be kept free from weeds during the spring and early summer, but no cultivation should be done after the middle of June, since after this date the tender bark of the young shoots is easily injured and the value of the sprouts greatly impaired. By the middle of September the shoots will have attained their full growth—from five to ten feet.

Cutting.—A willow culture set out in the spring can be cut for the first time the following fall or winter. They are cut every year from November until March, the essential point being to finish cutting before the sap rises in the spring. If this is not done, the stock bleeds at the cut, and the new growth is less vigorous. Cutting is done with a sharp hook, somewhat like a reaping hook, in a clean manner, close to the ground and without splitting the stock.

Preparing for Market.—Willows are sold both peeled and unpeeled. In the latter case the cutting is best done during December and January. If, however, they are to be peeled before going to market, February is the best month in which to cut. After cutting, the shoots are gathered into bunches, and placed, butts down, in water four or five inches deep. If the water is deeper than five inches they are liable to take root and are then hard to peel.

By about the first of May the sap will begin to rise and the bark will get loose. When this occurs, the time for peeling has arrived. This should be finished by the first of June, since by that time the bark will get dry again and cling to the wood. Various instruments are used in peeling willows, the so-called "jam" or "spring tong" being probably the most simple and practicable.

After peeling, the shoots are placed on racks and dried in the open air, a process which takes only a few hours and which should be accomplished as rapidly as possible, since long exposure to the sunlight causes them to lose their white color. This must be preserved in order to get the best market prices. But peeled and dried willows may be kept safely for years in a dry, darkened room.

Life.—Under fairly favorable conditions a willow culture will last twenty-five to thirty years, but this depends largely upon the nature of the soil. The writer has seen a willow culture in France which was forty-three years old and still in excellent condition; and again he has seen one in the same locality, on unsuitable ground, which had given out in twelve years.

Cost and Returns.—The first cost *per acre* of a willow culture is estimated as follows:

Planting, 15 days' labor, at $1.50 per day..............	$22.50
73,000 cuttings, at an average cost of 70 cents per 1,000..	51.10
	$73 60

To this must be added the cost of preparing the ground. Owing to the extremely varied conditions prevailing, it is impossible to give any definite figures. The cost may range from $3 to $60 or even more per acre.

The production of a willow culture, under favorable conditions, may be estimated as follows:

Yearly yield per acre, 3,400 pounds of willows, valued from 4 to 7 cents per pound; average, 5 cents per pound..		$170.00
Cost of cutting per acre........................	$18.00	
Cost of peeling per acre........................	67.00	
		85.00
Profit per acre		$85.00

These figures are from actual results attained in New Jersey during the past eight years.

PART IV.

The Iron and Zinc Mines.

By HENRY B. KÜMMEL.

Copper Deposits of New Jersey.

By WALTER HARVEY WEED.

The Mining Industry.

THE IRON MINES.

BY HENRY B. KÜMMEL.

The iron-mining industry in New Jersey during the year 1902 has shown a gratifying increase in production over the figures for 1901. This result is the more satisfactory since the shortage of anthracite during the closing months of the year tended to retard the work of blast furnaces, as well as to hinder the working of the mines themselves. Inasmuch as the greater part of the ore mined in the State goes at once to furnaces under the same management as the mines, any falling off in their product is immediately felt at the mines.

Apart from the increased production for 1902, a noteworthy feature of the year's work is the favorable development at the Basic Iron Ore Company's mine near Oxford Furnace, where a large body of soft magnetite, carrying about 5 per cent. of manganese, has been found. The largely increased production of the Hibernia mines, due chiefly to the extensive series of improvements instituted several years ago and still in progress, is also worthy of mention. The work of the magnetic sorter or cobber at No. 11 shaft, Hibernia, has proven so satisfactory and economical that a similar plant is being established at No. 9 shaft.

During the year the following mines were in operation, but not all of them continuously: At Oxford Furnace, Slope No. 3 (now known as the McKinley), Washington and the Basic Iron Ore Co.; at Stanhope, the Hude; at Hurdtown, the Hurd; at Weldon, the Weldon; at Port Oram, the Irondale group; at Mt. Pleasant, the Richard; at Mount Hope, the Washington, Elizabeth and Teabo; at Hibernia, the Andover, De Camp, Upper Wood, Wharton and Beach Glen; at Ringwood, the Ringwood group.

THE BASIC IRON ORE COMPANY MINE.

The Basic Iron Ore Co., operators; R. L. Ahlis, President; Erskine Hewitt, Secretary, 17 Burling Slip, New York.

This is the mine referred to in the Report for 1901 as the Osmun-Robeson mine, located near Oxford Furnace.

During the year the new shaft was sunk to a depth of 168 feet, the first 70 feet being through glacial drift. Below this it penetrated soft "clayey" material (so-called), which contained some hard masses of rock. This material is apparently disintegrated gneiss *in situ* or the result of pre-glacial mixing of materials along a depression. Firm rock was not reached in the shaft. At 75 feet and 128 feet drifts were run to the ore body, 30 feet to the southwest.

The ore body, where cut by the upper level, had a thickness of about 40 feet from the foot wall on the east to a "horse" of coarse pegmatitic granite. Two cross-cuts made through this, at an interval of about 50 feet showed its thickness to be two and a-half feet and 30 feet, respectively. Beyond the "horse" the ore-body was found to have a thickness of about 24 feet to the hanging-wall on the west. The ore on this level has already been blocked out, preparatory to removal by the "caving" system of mining.

On the 128-foot level a main drift has been run from the shaft to the ore-body, through it and some distance into the granite "horse." Branching drifts have also been run from the main drift to the ore-body to assist in drainage. Tunnels have been run both ways from the main drift along the foot-wall and along the "horse," and one or two cross-cuts made through the ore.

The ore-body was also drifted on from an old shaft, 300 feet or more southeast of the main shaft, at the 75-foot level, and reached in about 130 feet.

Both drifts from the main shaft to the ore-body through the foot-wall rock were in thoroughly soft and decomposed gneiss, largely, if not entirely, *in situ*. In the longer drift from the old shaft some firm layers of rock were penetrated, but for most of the way the rock was also decomposed. At the upper level the granite "horse" was extremely soft and clayey, the large crystals of feldspar being almost completely kaolinized. At the lower level (128 feet) the rock is somewhat harder, although yet much decayed. The rock of the hanging-wall, where reached on the upper levels, was likewise completely decomposed, but at the lower level it has not yet been exposed. The great thickness (70 feet) of the glacial drift, together with its unweathered character, indicates that the very deep weathering and complete decomposition of the underlying rock is due to pre-glacial disintegration. This locality is very near the extreme southern limit of the later glacial drift where the eroding power of the ice was not sufficient to remove the soft disintegrated material.

The ore-body is harder than the enclosing country rocks, but nevertheless it has been somewhat altered, and is a rather soft mixture of magnetite and limonite, averaging 45 to 50 per cent. of metallic iron, and from 4 to 7 per cent. of manganese. It runs too high in phosphorus for Bessemer steel.

Owing to the soft condition of the ore as well as of the walls and the very considerable amount of water, it is necessary to timber carefully all drifts as fast as cut. The ore is being blocked out by tunnels along the foot and hanging-walls with frequent cross-cuts from which "raises" will be made and higher drifts and cross-cuts run. After the ore is thus blocked out it will be removed by the "caving" process, beginning with the higher tiers.

All of the work during the year has been along the line of development, and the ore mined was incidental to this. Something over 8,000 gross tons were shipped to the Pequest Furnace of Messrs. Cooper & Hewitt.

THE OXFORD MINES, OXFORD FURNACE.

Empire Steel and Iron Co., Catasauqua, Pa., owners and operators. Mr. J. M. Fitzgerald, Secretary of the company, has kindly furnished the following data concerning these mines:

A central power plant has been erected during the past year to operate these mines—the Washington and McKinley (formerly known as Slope 3). The new plant consists of 750-horse power Sterling boilers, a Rand and an Ingersoll-Sergeant compressor, each of modern design and capable of compressing 2,000 feet of free air per minute to 90 pounds pressure, and the necessary intercoolers, after-coolers, condensers, pumps, receivers, &c. The air is conveyed to the Washington mine by a 10-inch pipe nearly 4,000 feet in length, and to the McKinley mine by a 6-inch branch about 1,000 feet in length.

A new shaft is being sunk at the Washington mine to give an additional exit and to improve the ventilation. The new shaft at the McKinley mine, noted in the Report for 1901, is nearly completed and it is expected that the output will soon be much increased.

The ore producton during the year at the Washington and McKinley mines amounted to 36,758 gross tons.

HUDE MINES, STANHOPE.

Musconetcong Iron Works, Philadelphia, lessees, John S. Kennedy, Stanhope, Manager.

Mr. Kennedy reports that these mines, which were reopened in October, 1901, after a period of idleness of several years, have been worked during 1902 upon the same basis and under the same management as in 1901. The ore mined, about 8,700 tons, was all hauled to the company furnace at Stanhope.

HURD MINE, HURDTOWN.

New Jersey Ore Company, Philadelphia, lessees; T. M. Williams, Mine Hill, Manager.

During the past year mining has been restricted to two workings on the southern side of the great offset, where there are at least four shoots of ore on the northwestern limb of a synclinal fold. The bottom of the fourth shoot, mentioned in the Report for 1901, was reached at about 175 feet, and it is now being followed northeastward toward the offset. The other working has also been south of the offset and on the hanging-wall side of the old turnpike openings. Here a horizontal body of ore, located by earlier prospects, has been found to change gradually to a nearly vertical dip, as it has been opened up. About 14,000 tons of ore have been taken from these two workings during the year, and it is certainly a matter for congratulation that this old mine, from which so many hundred thousands of tons of ore have been taken, should continue to be steady, even though a small producer.

THE WELDON MINE.

Berkshire Iron Co., New York, owners. L. Lea Clark, President and General Manager; Frederick Schlueter, Secretary and Treasurer.

During the year the Weldon mine was purchased by the above company, who have operated it since March. They have also purchased the Dodge mines at Ford, N. J., two miles northward. Numerous improvements have been made on the property, both above and under ground, and more are in contemplation. Owing to a temporary shutdown caused by the coal strike and necessary development work, the production of the mine for the year has been restricted to about 4,000 tons.

IRONDALE MINES, PORT ORAM.

New Jersey Iron Mining Company, owners.

The company reports that during the past year these mines have produced over 20,000 tons, in part from the New Sterling Slope, but chiefly through the Hurd slope which now has a depth on the incline of 1,100 feet. The new "sink" on the Sterling slope has been continued a depth of 90 feet, and a leader of ore has been followed all the way.

THE RICHARD MINE, MT. PLEASANT.

Thomas Iron Company; B. F. Fackenthal, Jr., President, Easton, Pa.; Mr. James Arthur, Superintendent, Port Oram, N. J.

This mine, by its production of 102,649 gross tons, continues to hold first rank among the iron mines of the State, although during the past year the production of the Wharton mine, at Hiberia, did not fall far short of the above figures. Owing, however, to the scarcity of anthracite during the latter six months of the year the work at the Richard was considerably curtailed, so that its production fell somewhat short of its star record of 1901.

MOUNT HOPE MINES, MOUNT HOPE.

Empire Steel and Iron Co., Catasauqua, Pa., owners and operators.

Mr. J. M. Fitzgerald, Secretary of the company, has furnished the following facts concerning these mines:

The Brown slope, started in 1901 to relieve the congestion in the Taylor mine, has been deepened and will soon be in such shape as will permit the opening of several levels from it. This will increase greatly the production from the Taylor vein.

Mining was also continued in the Taylor and Elizabeth mines during the year. The production from all these mines, including a small amount from old workings on this property, amounted to 20,454 gross tons.

TEABO MINE, MOUNT HOPE.

Joseph Wharton, owner; Edward Kelly, Manager.

Mr. Kelly reports that this old mine is now being developed by Mr. Wharton. A new shaft has been sunk to a depth of 240 feet, and about 1,000 tons of ore mined during the year. In the bottom of the shaft is a vein of ore about six feet wide, which contains 60 per cent. metallic iron.

HIBERNIA MINES, HIBERNIA, N. J.

Joseph Wharton, owner and operator; Edward Kelly, Manager, Wharton, N. J.

The effect of the many permanent improvements, both on the surface and underground, which have been made during 1900 and 1901 on this valuable line of mines, has been shown in their largely increased production during the past year. This is the more striking in that the scarcity and high price of coal during the latter part of the year had a tendency to restrict the output of many of the mines of the State.

Mr. Kelly has kindly furnished the following details regarding the workings during the year 1902:

The Andover Mine (formerly the Lower Wood & Crane).—The development during the year consisted in mining out the ore in stope 23 northeast to the De Camp line and southwest to the barren ground or so-called "bed-rock" and in sinking 50 feet to a new stope, No. 24, which was started. Stope 23 was also driven 60 feet southwest through this lean ground and there opened up a body of ore from seven to nine feet thick. It is expected to continue this stope still farther to the southwest to a point directly under the main skip-road, which is about 1,000 feet distant. When this is done all the water will flow by gravity to the main pump-shaft and relieve the congested condition of No. 16 and No. 19 inclines.

De Camp Mine.—The work on this property has been principally that of sinking the new skip-way, and is now about 510 feet below tunnel level. A considerable amount of ore, however, was mined during the year through No. 4 shaft. It is intended to install on this property during the coming year one 24 by 42-inch double cylinder, direct-connected hoister, by which the output will be largely increased.

The Upper Wood Mine.—The skip-road in this property has been extended from level No. 5 to level No. 8, thus increasing its depth 190 feet, and the new level No. 8 has been opened up, the vein in the bottom of the mine having a width of six feet.

A 24 by 43-inch, double cylinder, direct-connected hoister and a battery of 250-horse power of B. & W. boilers has been installed.

Wharton Mine.—No. 9 shaft has been sunk about 90 feet during the past year and has been a steady producer of ore. Heretofore this ore has been hand-cobbed, but the results obtained by the use of the magnetic cobber at No. 11 shaft have been so satisfactory that a similar cobbing plant is now being erected for use at No. 9. In the mine the development work has been such as will result in a largely increased output next year.

No. 11 shaft has been sunk about 60 feet and considerable mining done on the different levels. The magnetic cobbing-plant at this shaft has been a decided success, enabling the operator to prepare his ore at a remarkably low cost, and with very uniform results.

No. 12, or prospecting shaft, has been sunk to a depth of 560 feet. A cross-cut 80 feet long has been driven at a depth of about 380 feet, and a vein about 7 feet wide of lean ore discovered. No mining was done at this level, but another cross-cut is being driven at 560 feet, and at date of writing has progressed 10 feet. No marketable ore has been mined out of this shaft.

The Magnetic Separator.—This mill has been idle since November 1st, 1902, and is now being remodeled with a view of largely increasing the output at a lower cost of operation. During 1902 there were shipped from this mill 6,955 tons of concentrates and 30,100 tons of sand.

The total amount of ore mined and shipped from the various operations on the Hibernia vein in 1902 was 218,433 tons, including the product of the Separator.

THE BEACH GLEN MINES, BEACH GLEN.

Mr. Wharton surrendered his lease on this property early in the year. We are informed that later the mine was operated by the Beach Glen Mining Company, but we have not been able to obtain any further information concerning it.

RINGWOOD MINES, RINGWOOD, N. J.

Cooper, Hewitt & Co., owners.

Mr. Edward R. Hewitt reports that the Ringwood mines were operated during the past year and that 9,214 tons of ore were produced and shipped. This is a considerable falling off over the production of the previous year.

THE ZINC MINES.

Mr. James B. Tonking, the Superintendent, reports the following operations during the year 1902 at the zinc mines at Franklin Furnace, owned by the New Jersey Zinc Company.

At the northern end, or Parker mine, the work has consisted in extending the several levels in a southerly direction, as noted in former reports.

At the Taylor mine (commonly called the Buckwheat) the open work, which has consisted in removing the rock from the fold down to the tunnel level, was carried on continuously until about November 1st, since which time little has been done. There is not now a large quantity of rock to be removed, the southwest face of the dike being exposed for two-thirds of its length on a cross-section from east to west. Only a small portion of the ore exposed by this stripping on the west leg has been removed. The slope sunk from the trap-dike on the strike of the lens on the east leg was continued to the 700-foot level, when a diagonal drift was driven so as to intersect the west leg. After continuing the same for about 200 feet in a northerly direction, a winze was sunk through to the 750-foot level, intersecting the hanging-wall of the south drift from the Parker mine. This connection between the two mines makes ventilation perfect through all of the workings.

The Trotter mine was inactive throughout the year.

The amount of ore mined during the year, most of which was sent to the mill for separation, was 209,386.18 gross tons.

The Stirling Hill mines at Ogdensburg were inactive during the entire year.

Copper Deposits of New Jersey.*

BY WALTER HARVEY WEED, GEOLOGIST, U. S. G. S.

Introduction.—The existence of copper deposits in New Jersey has been known since the earliest settlement of the country, but the record of their later working shows a disheartening succession of failures. Recent development at one locality has, however, shown a very favorable change in the mineralogical conditions of the ore-body, a change of great import not only for this particular property, but also for the many similar properties of the State. It is the object of this paper to present these facts, and to discuss their bearing not only upon the genesis of these deposits and their alterations, but to show the commercial importance of testing the truth of the conclusions by actual exploitation.

History.—The copper deposits of New Jersey were worked to a limited extent in colonial days, chiefly by short tunnels or by mere quarrying out the bunches of rich surface ores. During the New Jersey campaign, Washington and the Revolutionary army made their winter camp on Watchung mountain, near Bound Brook, and the copper seam outcropping at this locality furnished ore enough for the manufacture of a brass cannon, which was afterwards used in the siege of Yorktown. Early in the nineteenth century the Griggstown, Somerville, Plainfield and Arlington localities were known and worked. In 1824 an expert smelterman was brought over from Germany and installed and worked a smelter near Bound Brook. A few years later he operated a small furnace near Belleville, N. J., the ore coming from the Schuyler mine, which was worked at intervals for the remainder of the century. Small furnaces were built in at least a dozen different places, and were, for those days, successful. Along Watchung mountain, from Plainfield west and

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north to the Raritan river, the ore-bed was opened by tunnels and open cuts, whose dump-heaps and pits, now more or less overgrown by vegetation, are clearly recognizable. I have myself counted twenty-one of these old workings in a distance of four and one-half miles along the mountain from Chimney Rock (Bound Brook) westward, and have also seen the ruins of three smelting furnaces. The period of greatest activity in this region was from 1825 to 1850. For the thirty years succeeding, the Arlington (Belleville) was the only one worked in a commercial way. About 1880 the American Copper Company was organized and acquired various small holdings, the various woodlots of the neighborhood farmers, scattered along the front of Watchung mountain, back of Somerville and Bound Brook, and embracing the old workings mentioned above. This property was worked until 1882, when operations were suspended, as the optimistic reports of its promoters were not realized. In 1889 exploratory work was resumed upon this property and continued for several years, but it was not until ten years later that the high price of copper led to a general renewal of interest in copper properties, and this property, with others at several different localities, was reopened and work of exploration and development resumed.

The gradual passage of the carbonate and oxide ores into native copper in sinking on the ore-bed of the Somerville, N. J., mine, occurring not merely as sheets, but disseminated through the rock, is new in the history of New Jersey. If, as seems likely, this change is a permanent one, as at Lake Superior and Bolivia, it is significant of a possible new and prosperous era for the New Jersey deposits.

Distribution and Occurrence of the Copper Ores.—Copper minerals occur at many localities in New Jersey, in the crystalline rocks and throughout the red sandstone areas. In the red sandstone areas copper ores are almost universally found associated with the trap-rocks, and the deposits of past or prospective commercial importance occur only in connection with these rocks. Thus the distribution of the ores is confined to that of the Triassic rocks,* and still further limited by the occurrences of the trap intrusions and extrusions of this series.

* Copper ores also occur in the Medina red sandstone in Pahaquarry township, Warren county, where they were mined in a small way in the seventeenth century by the early Dutch settlers.—H. B. K.

The red sandstone series of New Jersey consists essentially of red shales and sandstones, with associated white and gray sandstones and shales. The series is known as the Newark formation, and it extends from Connecticut southward to Virginia. The rocks contain fossil remains, which determine its age as Triassic, and it is furthermore characterized by gigantic foot-prints of great reptiles. The rocks were deposited in shallow estuarine areas, likened to that of the bays of our coast, an origin indicated by mud cracks, raindrop impressions, and the reptilian tracks already mentioned, as well as by the character and color of the rocks themselves. Where these rocks alone occur the country is devoid of all but slight elevation.

The trap-rocks are basic igneous rocks, of very uniform chemical composition, but varying physical texture, so that they vary from the basalts of Orange (Watchung) mountain, and dolerites to diabases. The trap-rocks of the Watchung mountains have been proven to be lava-flows, contemporaneous with the sandstones. The other trap-rocks of the State, whose most familiar example is seen in the Palisades of the Hudson river, are intrusive sheets. The smaller intrusions commonly follow shaly bands and often persistently adhere to a single horizon. The rocks adjacent to such sheets show the effects of heat and steam in the baking and alteration of the sediments, but such contact metamorphism is confined to a narrow band. Both sandstones and trap-sheets are tilted at generally gentle angles and are folded in synclines and anticlines. The trap-rocks form the ridges and mountains of this part of the State, their superior hardness enabling them to resist the erosion that has carried away so large a part of the shale and sandstone areas.

The trap-rock is dark bluish gray when freshly fractured, but turns greenish on exposure. It has an even-grained compact texture and consists of abundant pyroxene (probably malacolith, an iron-lime-magnesia pyroxene low in alumina), and of plagioclase feldspar (labradorite) in part altered to prehnite. The pyroxene and an original olivine has altered to chlorite. It is this which gives the dried rock its greenish tinge. There is also some magnetite present. The analyses VII. and VIII. of the table show the Orange mountain basalt and the New Haven diabase to be rocks of essentially the same chemical composition.

Structural Conditions.—As has been frequently pointed out in the previous reports of the State Geologist, the copper ores all occur either directly under or directly over the trap-sheets. The trap-sheets are very regular and the ore bodies are equally so. The regularity of this ore-bed is shown by the fact that it is proven to underlie the trap for a distance of at least eight miles. Above the trap-rock the sandstones are impregnated, but less regularly. Thus at the Arlington property the ore does not occur in a well-defined bed or vein, though it is confined to the sandstones for fifteen or twenty feet above the trap-sheet, occurring "in pockets or bunches and seams which ramify through two thick layers of sandstone and a thin bed of shale. There are numerous (slight) faults in the deposit, and it is at these points and in connection with small trap-dikes that some of the richest ore is found." Near the contact the sandstone is very generally though slightly impregnated with copper. The grayish sandstone above the traps of Watchung mountain is similarly impregnated. The structural conditions at Griggstown and the many other localities in the State where copper is found are similar. A few true veins also exist, but so far as known they are fractures later than the ore-beds, and their filling is the result of secondary processes.

Present Condition of the Mines.—At most of the deposits the old workings are inaccessible. Long tunnels are caved in and filled with water; shafts are blocked up and filled, but the extent of the workings early in the nineteenth century is known from the records and can be inferred from the great dump-heaps of waste and low-grade ore. At present the only underground workings accessible are those of the Griggstown, Arlington and Somerville properties.

At Arlington the old Schuyler mine is now the property of the Arlington Copper Mining Company. An expenditure of nearly $250,000 has been made here since 1900, mostly in the erection of an expensive reduction plant. This money was expended under the direction of an "expert" in the installation of a plant of unique design, with good machinery, but no local metallurgical value. It is designed to treat 125 tons a day, but when run on the ore it was found that the tanks would not hold the solution and the copper would not precipitate. The present manager, Mr. Wm. McKensie, is, however, conducting experimental runs which have thus far been very successful.

The property comprises 150 acres, in part honeycombed by old workings, comprising forty-two shafts, all but one now filled, and three drain tunnels, one of which drains the mine to the 100-foot level. Two inclines have been run in from the face of the sandstone bluff overlooking the Newark meadows. One incline is 220 feet long and connects through old workings with an old shaft. The second drift is but 80 feet long.*

The American Copper Mine Company own land underlain by the ore-bed outcropping for several miles along the escarpment of Watchung mountain. Their main working is, however, three miles from Somerville, at the site of the old Bridgewater mine, where an incline shaft 1,300 feet deep on the dip has been sunk on the ore-bed, with 1,800 feet or so of drifting. The drifts are thirty feet apart, alternating on each side, thus blocking out the ground in the same manner as in coal mining. No timber is used save for a few yards near the surface, and no shattering of rock has as yet occurred, the great trap-sheet, 600 feet thick, forming a perfect roof, so that using ore pillars and a cribbing of waste for support in stoping no timber is necessary. The development work is done with power drills, the softer fissile shale beds beneath the ore being first undercut and extracted as in coal mining, leaving a breast of ore easily shot down and free from waste. The development work thus far done has blocked out a large amount of ore, but as shown later, it is low-grade, and it is only below 600 or 700 feet where the change to native copper occurs that an ore averaging 1¼ per cent. can be profitably extracted. It should be stated, however, that systematic sampling by the Mine Superintendent, shows, I am told, over 2 per cent. of copper.

The surface plant consists of a 5-drill Rand compressor with 80-horse power boiler, now running two drills and the pumps, and a hoist with 12-horse power Lidgerwood engine. The 50-ton mill is equipped with 60-horse power boiler and engine, crusher, two sets roughing rolls, drying screens, sizer and two Wilfrey tables. Experiments in leaching the oxidized ores were made, but as the ore has changed to native copper in depth and this change appears likely to be permanent, the treatment is greatly simplified.

* Annual Report of the State Geologist for 1900, pp. 209–212.

The shot-like particles of copper in the concentrate from the Wilfley tables carry 60 per cent. copper.

Nature of the Ores.—The copper ores of New Jersey are commonly the oxides, carbonates and silicate of copper, of which cuprite, malachite and chrysocolla are the most common, the black oxide, tenorite, and the blue carbonate, azurite, being rare. Associated with these ores there are sheets and masses of native copper, in joints and crevices, of both trap-rock and ore-bed. Glance (chalcocite,) commonly associated with calcite, is also found. The other sulphides are rare, bornite occurring as a secondary product in the boulders of decomposed rock of the subsoil at Chimney Rock, and chalcopyrite at Arlington and other localities as a secondary mineral filling fractures. Native silver occurs at various localities associated with chrysocolla at Arlington, Somerville and Raritan river.

The workings early in the century, sometimes several hundred feet long, were abandoned because the hand-pumps would not handle the water. So far as known, the Somerville property, known as the American mine, is the only one that has penetrated below the water level and beyond the zone of surface oxidation and alteration. For this reason the discussion of mineralogical changes, permanency of ore and its genesis, is in large part based upon the facts observed and the specimens collected at this mine. This change is of great significance inasmuch as the commercial value of these low-grade deposits depend entirely upon it.

In studying the occurrence and distribution of the ore minerals it is necessary to distinguish the normal ore content of the vein (either unaltered or in its decomposition products) from the ore of secondary fractures extending down to considerable depths. The latter carry surface-waters and carbonate ores far below their normal level, and such ores are not a normal constituent of the deposit. The ores of the upper parts of the Somerville deposit are mainly red oxide of copper in nodules and bunches in the ore-bed, with films of native copper in joint cracks. The cuprite varies considerably in luster and color; bunches of several pounds' weight occur near the surface, where it is commonly surrounded by a crust of malachite and chrysocolla, often grading into a red or green jasperoid. In passing downward along the dip the carbonates disappear and red oxide is more abundant. This, in turn, changes to an earthy orange-powder or an aggregate of minute-needles of copper oxide, associated with native copper, the latter becoming more and more abundant in depth until no oxide is seen.

As shown by Dr. Cook* many years ago, the New Jersey copper deposits are not veins, but beds, either of sandstone above the trap-rocks, or altered shale beneath the trap-sheets. Where the trap is intrusive, as at Arlington, New Brunswick, Griggstown, &c., the adjacent rocks are more or less baked, altered by the heat of the igneous magma to contact metamorphic rocks, hornstones, &c. At Rocky Hill glance and hematite occur under conditions that suggest a hydrothermal origin, and at Arlington also the conditions indicate a reimpregnation of the overlying rocks, with subsequent slight alterations and migrations of the copper.

Occurrence of Ore at Somerville Mine.—The Watchung mountain deposits are by far the most extensive deposits of the State, and as the conditions throughout are apparently uniform, the occurrence at the American mine, near Somerville, is typical for the whole area. At Somerville the ore-bed is a dense and firm, nearly uniform, purple rock, having a texture like that of a brick on cross-fracture, and differing markedly in its massiveness and uniformity of texture from the underlying shales. This ore-bed varies from 8 inches to 2½ feet in thickness. The rock also differs markedly from the shale in color, being purplish in color, while the shale is red. This purple tint is characteristic, and even after a half century of weathering on dump-heaps is readily recognized. The earlier geologists recognized the changed appearance of the shale and assumed it to be due to contact metamorphism. It is quite possible that there has been a slight baking, for, although the evidence is conclusive that the Watchung sheets originated as lava flows, spreading out over the tidal flats or shallow reaches of a great estuary, yet the alteration which I have observed under lava-flows in the Yellowstone Park and elsewhere, is sufficient to produce the changes seen here. That this alteration is not wholly due to mere baking is shown by experiments with the underlying shale, and it is believed that later alteration has taken place. Especially interesting is the porous condition of the rock. It is permeated by a great number of gashes whose lenticular cross-sections and length have the appearance of gashes made by sticking the point of a penknife into a soft substance. Besides

* Geology of New Jersey, 1868, p. 675.

these open spaces there are many small irregular cavities. This porous texture is characteristic of both the purple rock and the white spots in it down to 1,300 feet from the outcrop.

The copper minerals are not uniformly disseminated through the ore-bed, but occur only in white spots or blotches irregularly scattered through the purple rock. In depth these spots, whose white or gray tint is in marked contrast to the purple rock, invariably carry ore, at first as oxide-dust, lining minute cavaties. later as small nuggets and pellets of native copper, disseminated through the light colored rock.

As a rule the copper partly or wholly fills these pores in the white blotches of the beds. In large part the rock of the ore-bed at 1,300 feet and below is solid, these pores being filled by calcite, the significance of which and the association of calcite and native copper, will be discussed later. Throughout most of the workings, however, not only of the American mine, but the adjacent properties, the rock of the ore-bed is distinguished by the above-mentioned pores.

The *shale* beneath the ore-bed is, where exposed by weathering, friable and soft. In the mine workings it is compact and hard, composed of different layers, which thin out abruptly, are often separated by micaceous partings and streaks, and vary in grain. Immediately beneath the ore the shale is very fine grained and dense, but shows calcite specks, and when treated with dilute acid the rock shows an abundance of pores, often irregularly round and branching, of the same shape as many of the smaller particles of native copper in the ore.

The base of the trap-rock is frequently amygdaloidal at the contact, the smaller cavities being filled by calcite, the larger sometimes with quartz, calcite, laumontite and manganocalcite.

The trap-rock at and for several inches from the contact shows considerable alteration. The rock contains many small shot amygdules of calcite the size and shape of fine birdshot. Six inches from the contact it is a nearly normal dark-gray color, greenish from chloritic staining when moist, but to the eye quite fresh and unaltered. At three inches from the contact the rock is slightly lighter, increasing gradually to a well-marked brownish line one millimetre thick at one and one-half inches from the contact. A second chocolate-colored line one-eighth of an inch from the first, with a third one-sixteenth of an inch, inside of which the lines become indistinct and merged in a general brown staining of the rock for half an inch, with more abundant calcite amygdules. The trap for an inch from the contact is much lighter colored and shows a great abundance of calcite amygdules, mostly of irregular shape and bordered or encrusted with shells of native copper.

An examination of thin sections of the ore under the microscope shows that the purple rock, although in reality an *altered shale*, has the appearance of an altered igneous rock. In fact, from the slide alone, Professor Joseph Barrell, who has kindly examined it for me, concluded that the rock is a vitrophyric andesite, showing small broken feldspar crystals, and shreds of muscovite in a glass base stained deep red by ferric oxide. The sharp feldspar crystals in marked distinction to the isotropic groundmass seem to indicate that this rock is a chilled margin of the diabase, but comparison with thin sections of the red shales shows that this distinction is not a sure one. Moreover, the ore-bed shows micaceous partings and streaks of compact very fine grained shale, and sometimes has fossil mud cracks. Despite its physical texture, therefore, these evidences show that it is merely an altered shale. This conclusion is, moreover, sustained by a comparison of the chemical analyses of the ore-rock with those of the underlying normal shales, as shown in the table below.

The analyses given below were made by the chemist of the American Copper Company, and furnished me by the courtesy of Mr. Josiah Bond, General Manager. The first column represents the trap-rock, the fourth the ore. It will be noted that the large percentage of alumina and very slight amount of alkalies present in No. IV. shows the rock to be a normal sediment. The ore proper, that is, the white copper-bearing spots in the purple gangue, evidently result from the reducing action that produced the native copper and changed the red ferric oxide to the protoxide. Tests made in the Survey laboratory by Dr. Stokes, upon samples of these rocks, showed the presence of ferric oxide in the red and the presence of ferrous iron in the white rock, a conclusion confirmed by an examination of thin sections under the microscope.

TABLE OF CHEMICAL ANALYSES OF ROCKS, AMERICAN COPPER MINE, SOMERVILLE, N. J.

	I. Trap.	II. Shale.	III. Shale.	IV. Purple ore.	V. White ore.	VI. Ore.	VII. Basalt.	VIII. Diabase.
Silica	44.84	57.45	57.02	57.24	50.15	59.68	51.86	51.75
FeO	4.3	1.54	1.93	*6.21	3.57	6.29	8.24	8.25
Fe_2O_3	6.81	9.61	8.72	....	....	....	2.14	3.59
Al_2O_3	17.68	21.19	19.60	24.31	19.07	26.85	16.25	12.79
MgO	8.90	0.83	0.76	3.20	1.74	1.71	7.97	MnO. 0.09 NiO. 0.08 7.63
K_2O	1.86	0.63	0.75	....	Trace.	....	1.06	0.89
Na_2O	1.80	0.26	0.19	....	Trace.	....	1.54	2.14
CaO	10.70	4.00	6.78	5.80	14.64	4.18	10.27	10.70
Ignition	8.20	4.12	4.01	3.08	7.44	1.75	1.33	.63
Copper	(H_2O 8.17)	Trace.	Trace.	Trace.	†3.01	....	....	TiO_2 1.41
	....	....	....	99.84	....	....	100.28	99.89

* Iron as Fe_2O_3

† Silver 1.9 ounce per ton.

I. Trap-rock from above ore-bed, American copper mine
II. First shale layer below ore-bed, " " "
III. Second " " " " " " "
IV. Purple rock of ore-bed, " " "
V. White spots in "
VI. Ore.
VII. Basalt—normal rock of Watchung mountain, Orange, N. J
Bull. 148, U. S. G. S., p. 80.
VIII. Diabase, West Rock, New Haven, Conn.

Analysis I. shows, in the high percentage of water and ignition and the low silica, that the rock is much altered, compared with VII., which is the normal rock at Orange. The analysis I. shows normal alumina, alkalies and lime; the iron has largely altered to the higher oxide. There is a loss of 50 per cent. of magnesia as compared with the Orange rock, and a decided loss of silica. These changes indicate a leaching of the rock by alkaline waters, and the unchanged alkalies show that there was no available chlorine or sulphur to combine with and remove them.

The shale analyses are unusual in showing no alkalies. It is normal for a slightly calcareous clay shale.

Analysis IV. represents the normal rock of the ore-bed. It shows a silica content exactly like that of the underlying shale and unlike the trap-rock. It differs from the underlying shale in having much less iron, more alumina, with considerably more magnesia. It resembles the shale in having no alkalies.

The alteration of the trap is evidently the result of normal hydrometamorphism.

Occurrence of Copper in the Ore-bed.—*Copper glance* (chalcocite,) occurs in small quantities at numerous places in the mine, mainly as a secondary product in fractures. Below the zone of oxidized ores it occurs in and with calcite in joint fractures, often associated with sheets of native copper.

The masses of white ore-bearing rock of the lower drifts (1,300 feet and 1,330 feet) also carry glance. In the purple rock surrounding the white ore the glance occurs as tiny bunches of glistening crystals, attached to the walls of the gash-like cavities. In the white ore the glance occurs in solid nucleal masses, dull on existing fracture surfaces and surrounded by sooty glance (an alteration product), a substance which has also in many instances migrated and impregnated the porous rock about the cavity. The most significant feature is, however, the presence of native copper about this altered glance, usually bordering it, and whose extremely finely divided state and manner of occurrence show it to be reduced from the glance *in situ*. In several instances these spots of native copper or of glance and copper are surrounded by a halo of bleached rock, whose width is one-half the diameter of the cavity, clearly indicating an alteration due to the product of the reactions involved in reducing glance to native copper. The glance just described is not associated with calcite, but occurs in cavities.

Glance also occurs in drusy masses and along joint fractures as a crystalline mass of calcite enclosing a mesh of very minute mossy hairs of glance. This association indicates the synchronous deposition of both materials. At present it appears as if this glance was an instance of reversible reaction, *i. e.,* native copper and calcite attacked, calcite removed, glance deposited. Later solutions attack glance, *in the white rock* and reduce it. It is especially significant that *no* native copper occurs in the red rock (*i. e.,* in presence of ferric oxide) but that it is confined to and being reduced in white rock (no ferric oxide, but ferrous iron). If this is so the cause is purely local.

Association of Native Copper and Calcite.—Native copper occurs encrusting and sheathing calcite amygdules in the trap and the similar calcite masses in the white ore. I also saw native copper pseudomorphic after crystals of calcite in the collection at the mine. This occurrence of native copper in white bleached spots in the ore-bed is a marked characteristic of the great copper deposits of the red sandstones of Corocoro, Bolivia,* and similar features were noted in 1902 by Emmons.† Native copper pseudomorphic after calcite also occurs at Corocoro and Lake Superior.

Kemp‡ notes that the comparison drawn by early investigators between the Lake Superior and New Jersey deposits is quite significant, although there is a very great difference of age. The Lake Superior deposits do not pass into sulphides in depth, except locally, *i. e.*, at the Huron mine, copper arsenide occurred, and native copper changes to glance ninety feet down in the Mamaisne mine near Sault Ste. Marie. At Corocoro, cited above, similar ores occur.

Origin of the Copper.—The copper is believed to come from the trap-rocks, and not the shales, a theory suggested by Kemp. The evidence of this is, first, 200 assays of the basalt of the Watchung mountain sheet, made for Josiah Bond, by the most refined chemical methods, gave one-fortieth of one per cent. as the average copper contents of the basalt. Second, the nucleal contents of large trap prisms, showing no alteration, were crushed, the heavier mineral concentrated by "horning," and the result, tested for me by Dr. Hillebrand, showed an appreciable amount of copper.

Even if the New Jersey trap did not contain copper its association with the deposits is a genetic one, if the ferrous salts of the altered rock acted as the precipitating and reducing agent for the native copper, in accordance with the accepted theory for Lake Superior deposits. Van Hise, following Pumpelly and Irving, says of the occurrence of native copper about magnetite grains in the Lake Superior rocks: "It seems perfectly (p. 344, Principles, &c.), clear that the protoxide of iron in the magnetite was the reducing agent which precipitated the metallic copper. The metallic copper between the particles was doubtless precipitated by ferrous solutions furnished by the wall-rocks which in many cases are basic volcanics."

* David Forbes, Quarterly Journ. Geol. Soc., Nov., 1860, p. 41.

† Verbal communication.

‡ Ore deposits, p. 168, 2d ed.

RECAPITULATION.

Summarizing the observed facts that bear upon the discussion of origin of the Somerville deposit, we have:

The basalt is chloritized as a result of ordinary hydrometamorphism. It is vesicular in places, the cavities now filled with calcite amygdules. Native copper occurs sheathing these amygdules, in the leached and green rock an inch or two thick, next the contact, but only where the underlying rock of the ore-bed is *dense;* when it is porous the copper is absent in the basalt, but occurs in the altered shale.

The ore-bed is an altered shale beneath the basalt. It has a purple color, contains a large amount of ferric iron, and is distinguished by cavities whose shape, size, abundance and inner surface closely resemble the pores of an ordinary red brick, suggesting a slight baking of a wet silt or mud. These pores are either open or partly or wholly filled by native copper below the zone of surface alteration; filled by a loose powder of orange-colored oxide at the transition line and by normal oxides encrusted by carbonates above. This native copper and most of the oxide ore is confined to patches of white bleached parts of the ore-bed, irregularly distributed. In depth the cavities of the white ore are filled by calcite sheathed by native copper, but other parts of bed show fresh glance crystals in cavities in the purple ore and altered glance and native copper reduced from it, in cavities in the white ore. The latter are surrounded by a halo of whitened gangue. The sheet copper of these bottom workings occurs in joints parallel to bedding and near the trap contact; the native copper lies alongside of layers of black calcite, consisting of calcite shot through with minute spicules and mossy fibers of glance.

These facts are believed to show that the copper comes from the basalt; that the solutions carrying it contained alkaline carbonates, and precipitated copper and glance with calcite. If the copper came from decomposing chalcopyrite of either the shale or basalt the solution would be acid and calcite attacked. Where organic matter, such as plant remains, occurred the copper sulphide would be reduced to native copper.

The glance and calcite associated together in joints and fractures are regarded as secondary because they appear to be connected with a fault fracture permitting access of surface waters to the deeper workings along this fracture, and the deposits are confined to this fault and its proximity. They are regarded due to secondary enrichment. Concerning the glance in the pores of the ore-bed, I am uncertain, but believe it is primary. It is hard to see how any single chemical sequence can account for facts apparently so contradictory, and it may be like Vogt's Norwegian cases, an example of reversed conditions. The following appears to be the sequence of events:

(*a*) The basalt is chloritized and the iron reduced from silicate to ferrous oxide; (*b*) calcite amygdules formed in the basalt and pores of the altered shale bed; (*c*) copper is dissolved out by percolating waters and migrates toward the porous ore stratum beneath; (*d*) copper and calcite are deposited in the pores of the ore; (*e*) glance is reduced and ferric oxide is reduced in white patches.

The readiest reagent at hand to reduce the glance to native copper is humic acid in waters containing oxygen.

$$Cu_2S + C + H_2O + 5O = 2Cu + H_2SO_4 + CO_2.$$

There is no doubt that in some cases carbonaceous matter has produced a direct reduction of the sulphide to the native metal.

From the complete absence of iron oxide with the copper ore, and from the fact that the native copper occurs *only* in those portions of the ore-bed in which the ferric oxide has been reduced, a phenomenon common to Bolivian and European deposits as well as these, it is evident that the commonly accepted explanation is not only not adequate, but contrary to the observed facts. If it were the protoxide of iron or of magnetite ferrous solutions that caused the reductions we should have red spots and *ferric* oxide, one of the most insoluble and stable of substances, associated with the native copper. Moreover, the very common association of calcite quartz, chlorite and epidote observed in Appalachian* deposits, Lake Superior† and Oregon‡ show a genetic relation, which in connection with the fact of occurrence, show that carbonated meteoric waters traversing basic igneous rocks, carry silica, carbonate of lime and ferrous salts in solution, together with copper

* Weed, Types Southern Copper Deposits. Tran. A. I. M. E., 1900.

† Pumpelly, A. J. Sci., 1871.

‡ Lindgren, Geol. Blue Mtns., Oregon. Ann. Rept. Geol. Survey, 1901.

present as CuO. This is reduced by waters holding humic acid and free oxygen, producing the mineral mentioned.

Conclusions.—The commercial importance of these New Jersey deposits depends upon the cost of mining and extraction. The labor conditions and cost of supplies are considerably more favorable than in the Lake Superior region and the ore is more easily crushed. The metal occurs native in the lower workings, but the existing work does not furnish conclusive proof that this will not change to glance in depth. If it does not so change, and the average tenor of the ore proves over 1¼ per cent. and the copper native and concentrating readily on Wilfrey tables, there is a bright future for the properties when worked on a very large scale. Before erecting large reduction works it is absolutely necessary to explore and open up sufficient ground to permit of the steady extraction of a large quantity of ore daily. This underground work will also test the character of the ore and solve any doubt as to the continuance of the disseminated native copper in depth.

Mineral Statistics

For the Year 1902.

IRON ORE.

The total production of the mines, as reported by the several mining companies, was 443,728 tons.*

The total shipments from mines in the State, as reported by the railway companies, to the office of the Geological Survey, plus a small amount hauled by wagons to furnaces, amounted to 399,984 tons.

The table of statistics is reprinted, with the total amount for 1902 added.

TABLE OF STATISTICS.

Year.	*Iron Ore.*	*Authority.*
1790	10,000 tons	Morse's estimate.
1830	20,000 tons	Gordon's Gazetteer.
1855	100,000 tons	Dr. Kitchell's estimate.
1860	164,900 tons	U. S. census.
1864	226,000 tons	Annual Report State Geologist
1867	275,067 tons	" " "
1870	362,636 tons	U. S. census.
1871	450,000 tons	Annual Report State Geologist.
1872	600,000 tons	" " "
1873	665,000 tons	" " "
1874	525,000 tons	" " "
1875	390,000 tons	" " "
1876	285,000 tons†	" " "
1877	315,000 tons†	" " "
1878	409,674 tons	" " "
1879	488,028 tons	" " "
1880	745,000 tons	" " "
1881	737,052 tons	" " "
1882	932,762 tons	" " "
1883	521,416 tons	" " "
1884	393,710 tons	" " "

*A small amount mined at the Beach Glen and one or two other mines is not included, as reports have not been received.

† From statistics collected later.

Year.	*Iron Ore.*	*Authority.*
1885......	330,000 tons......	Annual Report State Geologist.
1886......	500,501 tons......	" " "
1887......	547,889 tons......	" " "
1888......	447,738 tons......	" " "
1889......	482,109 tons......	" " "
1890......	552,996 tons......	" " "
1891......	551,358 tons......	" " "
1892......	465,455 tons......	" " "
1893......	356,150 tons......	" " "
1894......	277,483 tons......	" " "
1895......	282,433 tons......	" " "
1896......	264,999 tons......	" " "
1897......	257,235 tons......	" " "
1898......	275,378 tons......	" " "
1899......	300,757 tons......	" " "
1900......	342,390 tons*.....	" " "
1901......	401,151 tons......	" " "
1902......	443,728 tons......	" " "

* The figures, 407,596 tons, given in the report for 1900, included 75,206 tons of crude material, which should have been reduced to its equivalent in concentrates.

ZINC ORE.

The production of the New Jersey Zinc Company's mines is reported by Mr. James B. Tonking, Superintendent, to be 209,386 gross tons of zinc and franklinite ore. It was chiefly separated at the company's mills. The amount of separates and ore shipped by the railroad is reported to be 192,192 gross tons. Both reports show a gain in production over 1901.

The statistics for a period of years are reprinted from the last annual report.

ZINC ORE.

Year.	*Zinc Ore.*	*Authority.*
1868......	25,000 tons†.....	Annual Report State Geologist.
1871......	22,000 tons†.....	" " "
1873......	17,500 tons......	" " "
1874......	13,500 tons......	" " "
1878......	14,467 tons......	" " "
1879......	21,937 tons......	" " "
1880......	28,311 tons......	" " "
1881......	49,178 tons......	" " "
1882......	40,138 tons......	" " "

† Estimated for 1868 and 1871. Statistics for 1873–1890, inclusive, are for shipments by railway companies. The later reports are from zinc-mining companies.

Year.	*Zinc Ore.*	*Authority.*
1883......	56,085 tons......	Annual Report State Geologist.
1884......	40,094 tons......	" " "
1885......	38,526 tons......	" " "
1886......	43,877 tons......	" " "
1887......	50,220 tons......	" " "
1888......	46,377 tons......	" " "
1889......	56,154 tons......	" " "
1890......	49,618 tons......	" " "
1891......	76,032 tons......	" " "
1892......	77,298 tons......	" " "
1893......	55,852 tons......	" " "
1894......	59,382 tons......	" " "
1895*		
1896......	78,080 tons......	" " "
1897......	76,973 tons......	" " "
1898......	99,419 tons......	" " "
1899......	154,447 tons......	" " "
1900......	194,881 tons......	" " "
1901......	191,221 tons......	" " "
1902......	209,386 tons......	" " "

* No statistics were published in the Annual Report for 1895.

Publications.

The demand for the publications of the Survey is continuous and active. So far as possible requests for the reports are granted.

It is the wish of the Board of Managers to complete, as far as possible, incomplete sets of the publications of the Survey, chiefly files of the Annual Reports in public libraries, and librarians are urged to correspond with the State Geologist concerning this matter.

By the act of 1864 the Board of Managers of the Survey is a board of publication, with power to issue and distribute the publications as they may be authorized. The Annual Reports of the State Geologist are printed by order of the Legislature as a part of the legislative documents. They are distributed by the State Geologist to libraries and public institutions, and, as far as possible, to any who may be interested in the subjects of which they treat.

Five volumes of the Final Report series have been issued. Volume I., published in 1888, has been very scarce for several years, but all the valuable tables were reprinted in an appendix of Volume IV., which can still be supplied.

The appended list makes brief mention of all the publications of the present Survey since its inception in 1864, with a statement of the editions now out of print. The reports of the Survey are distributed without further expense than that of transportation. Single reports can usually be sent more cheaply by *mail* than otherwise, and requests should be accompanied by the proper postage as indicated in the list. Otherwise they are sent *express collect.*

The maps are distributed only by sale, at a price, 25 cents per sheet, to cover cost of paper, printing and transportation. In order to secure prompt attention requests for both reports and maps should be addressed simply "State Geologist," Trenton, N. J.

CATALOGUE OF PUBLICATIONS.

GEOLOGY OF NEW JERSEY. Newark, 1868, 8vo., xxiv+899 pp. Out of print.

PORTFOLIO OF MAPS accompanying the same, as follows:

1. Azoic and paleozoic formations, including the iron-ore and limestone districts; colored. Scale, 2 miles to an inch.

2. Triassic formation, including the red sandstone and trap-rocks of Central New Jersey; colored. Scale, 2 miles to an inch.

3. Cretaceous formation, including the greensand-marl beds; colored. Scale, 2 miles to an inch.

4. Tertiary and recent formations of Southern New Jersey; colored. Scale, 2 miles to an inch.

5. Map of a group of iron mines in Morris county; printed in two colors. Scale, 3 inches to 1 mile.

6. Map of the Ringwood iron mines; printed in two colors. Scale 8 inches to 1 mile.

7. Map of Oxford Furnace iron-ore veins; colored. Scale, 8 inches to 1 mile.

8. Map of the zinc mines, Sussex county; colored. Scale, 8 inches to 1 mile.

A few copies are undistributed.

REPORT ON THE CLAY DEPOSITS of Woodbridge, South Amboy and other places in New Jersey, together with their uses for fire-brick, pottery, &c. Trenton, 1878, 8vo., viii+381 pp., with map.

A PRELIMINARY CATALOGUE of the Flora of New Jersey, compiled by N. L. Britton, Ph.D. New Brunswick, 1881, 8vo., xi+233 pp. Out of print.

FINAL REPORT OF THE STATE GEOLOGIST. Vol. I. Topography. Magnetism. Climate. Trenton, 1888, 8vo., xi+439 pp. Very scarce.

FINAL REPORT OF THE STATE GEOLOGIST. Vol. II. Part I. Mineralogy. Botany, Trenton, 1889, 8vo., x+642 pp. (Postage, 25 cents).

FINAL REPORT OF THE STATE GEOLOGIST. Vol. II. Part II. Zoology. Trenton, 1890, 8vo., x+824 pp. (Postage, 30 cents).

REPORT ON WATER-SUPPLY. Vol. III. of the Final Reports of the State Geologist. Trenton, 1894, 8vo., xvi+352 and 96 pp. (Postage, 21 cents).

REPORT ON THE PHYSICAL GEOGRAPHY of New Jersey. Vol. IV. of the Final Reports of the State Geologist. Trenton, 1898, 8vo., xvi+170+200 pp. (Postage, 24 cents).

REPORT ON THE GLACIAL GEOLOGY of New Jersey. Vol. V. of the Final Reports of the State Geologist. Trenton, 1902, 8vo., xxvii+802 pp. (Sent by express, 35 cents if prepaid, or charges collect).

BRACHIOPODA AND LAMELLIBRANCHIATA of the Raritan Clays and Greensand Marls of New Jersey. Trenton, 1886, quarto, pp. 338, plates XXXV. and Map. (Paleontology, Vol. I.). (By express).

GASTEROPODA AND CEPHALOPODA of the Raritan Clays and Greensand Marls of New Jersey. Trenton, 1892, quarto, pp. 402, plates L. (Paleontology, Vol. II.). (By express).

ATLAS OF NEW JERSEY. The complete work is made up of twenty sheets, each 27 by 37 inches, including margin, intended to fold once across, making the leaves of the Atlas 18½ by 27 inches. The location and number of each map are given below. Those from 1 to 17 are on the scale of one mile to an inch.

No. 1. Kittatinny Valley and Mountain, from Hope to the State line.
No. 2. Southwestern Highlands, with the southwest part of Kittatinny valley. Out of print at present.
No. 3. Central Highlands, including all of Morris county west of Boonton, and Sussex south and east of Newton.
No. 4. Northeastern Highlands, including the country lying between Deckertown, Dover, Paterson and Suffern. Out of print at present.
No. 5. Vicinity of Flemington, from Somerville and Princeton westward to the Delaware. Out of print at present.
No. 6. The Valley of the Passaic, with the country eastward to Newark and southward to the Raritan river.
No. 7. The Counties of Bergen, Hudson and Essex, with parts of Passaic and Union. A revised edition is being prepared.
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