DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 25

WATER RESOURCES OF THE STATE OF NEW YORK
PART II.—RAFTER

WASHINGTON
GOVERNMENT PRINTING OFFICE
1899

IRRIGATION REPORTS.

The following list contains the titles and brief descriptions of the principal reports relating to water supply and irrigation, prepared by the United States Geological Survey since 1890:

1890.

First Annual Report of the United States Irrigation Survey, 1890; octavo, 123 pp.

Printed as Part II, Irrigation, of the Tenth Annual Report of the United States Geological Survey, 1888-89. Contains a statement of the origin of the Irrigation Survey, a preliminary report on the organization and prosecution of the survey of the arid lands for purposes of irrigation, and report of work done during 1890.

1891.

Second Annual Report of the United States Irrigation Survey, 1891; octavo, 395 pp.

Published as Part II, Irrigation, of the Eleventh Annual Report of the United States Geological Survey, 1889-90. Contains a description of the hydrography of the arid region and of the engineering operations carried on by the Irrigation Survey during 1890; also the statement of the Director of the Survey to the House Committee on Irrigation, and other papers, including a bibliography of irrigation literature. Illustrated by 29 plates and 4 figures.

Third Annual Report of the United States Irrigation Survey, 1891; octavo, 576 pp.

Printed as Part II of the Twelfth Annual Report of the United States Geological Survey, 1890-91. Contains "Report upon the location and survey of reservoir sites during the fiscal year ended June 30, 1891," by A. H. Thompson; "Hydrography of the arid regions," by F. H. Newell; and "Irrigation in India," by Herbert M. Wilson. Illustrated by 93 plates and 190 figures.

Bulletins of the Eleventh Census of the United States upon irrigation, prepared by F. H. Newell; quarto.

No. 35, Irrigation in Arizona; No. 60, Irrigation in New Mexico; No. 85, Irrigation in Utah; No. 107, Irrigation in Wyoming; No. 153, Irrigation in Montana; No. 157, Irrigation in Idaho; No. 163, Irrigation in Nevada; No. 178, Irrigation in Oregon; No. 193, Artesian wells for irrigation; No. 198, Irrigation in Washington.

1892.

Irrigation of western United States, by F. H. Newell; extra census bulletin No. 23, September 9, 1892; quarto, 22 pp.

Contains tabulations showing the total number, average size, etc., of irrigated holdings, the total area and average size of irrigated farms in the subhumid regions, the percentage of number of farms irrigated, character of crops, value of irrigated lands, the average cost of irrigation, the investment and profits, together with a résumé of the water supply and a description of irrigation by artesian wells. Illustrated by colored maps showing the location and relative extent of the irrigated areas.

1893.

Thirteenth Annual Report of the United States Geological Survey, 1891-92, Part III, Irrigation, 1893; octavo, 486 pp.

Consists of three papers: "Water supply for irrigation," by F. H. Newell; "American irrigation engineering" and "Engineering results of the Irrigation Survey," by Herbert M. Wilson; and "Construction of topographic maps and selection and survey of reservoir sites," by A. H. Thompson. Illustrated by 77 plates and 119 figures.

A geological reconnoissance in central Washington, by Israel Cook Russell, 1893; octavo, 108 pp., 15 plates. Bulletin No. 108 of the United States Geological Survey; price, 15 cents.

Contains a description of the examination of the geologic structure in and adjacent to the drainage basin of Yakima River and the great plains of the Columbia to the east of this area, with special reference to the occurrence of artesian waters.

1894.

Report on agriculture by irrigation in the western part of the United States at the Eleventh Census, 1890, by F. H. Newell, 1894; quarto, 283 pp.

Consists of a general description of the condition of irrigation in the United States, the area irrigated, cost of works, their value and profits; also describes the water supply, the value of water, of artesian wells, reservoirs, and other details; then takes up each State and Territory in order, giving a general description of the condition of agriculture by irrigation, and discusses the physical conditions and local peculiarities in each county.

Fourteenth Annual Report of the United States Geological Survey, 1892-93, Part II, Accompanying papers, 1894; octavo, 597 pp.

Contains papers on "Potable waters of the eastern United States," by W J McGee; "Natural mineral waters of the United States," by A. C. Peale; and "Results of stream measurements," by F. H. Newell. Illustrated by maps and diagrams.

(Continued on third page of cover.)

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UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

WATER RESOURCES

OF THE

STATE OF NEW YORK

PART II

BY

GEORGE W. RAFTER

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1899

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DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, November 26, 1898.

SIR: I have the honor to transmit herewith a manuscript on the Water Resources of the State of New York, prepared by Mr. George W. Rafter, and to recommend that it be published as one of the series of papers on Water Supply and Irrigation.

This manuscript is a continuation of the material printed in Water-Supply Paper No. 24, which related mainly to the physical conditions of river systems of the State of New York, and particularly to the available water supply, the floods, and the low water of some of the typical streams. In the present paper a discussion is given of water-storage projects and of the development of water power and waterways. The paper as originally presented was intended for publication as a whole in one of the annual reports. This was found impracticable, and to secure publication at an early date it has been necessary to subdivide the manuscript to conform with the limitations imposed regarding the size of papers in this series. In spite of this disadvantage it is believed that the information contained in these two papers (Nos. 24 and 25) will be of value not only to the people of New York, but to those of other States.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

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

WATER RESOURCES OF THE STATE OF NEW YORK, PART II.

By George W. Rafter.

WATER-STORAGE PROJECTS.

Among the projects for storing water for power and other purposes are two of special importance with which the author has been concerned; the first of these is on Genesee River and the second on Hudson River. The following statements are for the most part condensed from more detailed reports in the Annual Report of the State Engineer and Surveyor for 1896.

GENESEE RIVER STORAGE RESERVOIR.

A general description of this river has been given in Part I (Water-Supply Paper No. 24), on page 25; its discharge measurements have been discussed on page 70, and reference has been made on page 90 to the low-water flow, indicating that during the summer the available supply is small. In spite of this fact, development of water power has proceeded rapidly. As shown by the reports on the Water Power of the United States in the Tenth Census (1880), the total water power on Genesee River from Rochester to Portage in 1882 was 6,882 net horsepower. An examination of the amount in use on the same reach of river in 1896 showed that the total, based on manufacturers' rating of wheels, was 19,178 net horsepower, or based on the manufacturers' statements of the quantity of water required to operate the wheels, and allowing 75 per cent efficiency of the water, the total power developed by the wheels in place in 1896 is found to be 17,248 net horsepower, or about three times that in 1882. In comparison with the figures it should be noted that for several months during the summer and fall of 1895 the total power did not exceed 6,000 horsepower. The same condition has existed during the dry period of a number of years previous, but not so seriously as in the fall of 1895.

PRELIMINARY INVESTIGATIONS.

The increased demand for power, as well as the serious summer droughts, led to the formulation of a project for constructing a storage reservoir at some point on the head waters of Genesee River for assisting the summer flow. The first project included the development of the basin of Honeoye Lake to its full capacity, surveys having been made for that purpose in 1887 and 1888. It appeared, however, that the yield of this drainage basin, which is only about 43.5 square miles, was hardly adequate for the results desired, the estimate showing that even when developed to its full capacity it could not be depended on to furnish, in a dry year, more than 75 cubic feet per second, while the exigencies of the case demanded at least several hundred cubic feet per second. The project of building a large storage reservoir on upper Genesee River was then formulated by the Rochester Chamber of Commerce.

In the meantime a number of breaks on the long level of the Erie Canal, which extends from the foot of the locks at Lockport to the eastern part of the city of Rochester, a distance of about 62.5 miles, had emphasized the importance of the State's providing additional water for feeding the canal east of Rochester. For this purpose the construction of a large storage reservoir was advocated by the Rochester Chamber of Commerce as a State work, with the result that under a resolution of the senate dated March 21, 1889, the State engineer and surveyor was directed to make a general investigation in regard to the possibility of storing water on the upper Genesee. The report made under the authority of this resolution appears in the Annual Report of the State Engineer and Surveyor for the year 1890. In 1892, under authority of a concurrent resolution dated March 15 of that year, Governor Flower appointed a commission consisting of Evan Thomas, Judge Charles McLouth, and John Bogart to investigate and report on the whole question of storage on the upper Genesee. This commission examined the site of the proposed reservoir and reported that it was entirely feasible to construct a large reservoir on the upper Genesee River, the site especially considered by the commission being in the Genesee canyon or gorge, a short distance above Mount Morris, already described in Part I.

As the result of the recommendations of this commission, the sum of $10,000 was appropriated at the legislative session of 1893 for the purpose of studying in detail the several proposed sites for dams in the canyon of Genesee River, above Mount Morris. At that time the work was placed in charge of the author, and has since remained in his hands.[1]

At the legislative session of 1894 a bill to construct a dam in the canyon a short distance above Mount Morris passed the senate, but

[1] The result of the studies in 1893 may be found in the Annual Reports of the State Engineer and Surveyor for the fiscal years ending September 30, 1893 and 1894.

failed in the assembly. At the session of 1895 a similar bill passed both the senate and assembly, but was vetoed by Governor Morton, largely on the ground that the bill as passed made no provision for the owners of the water power and other interested parties bearing any portion of the expense. In his veto Governor Morton expressed the belief that if the State should determine to build a dam on Genesee River some provision should be made by which the city of Rochester—and possibly other localities interested in the work—might contribute to the expense of construction. Governor Morton also pointed out that if the proposed canal enlargement be approved by the people public sentiment might justify the construction of a storage dam on Genesee River for canal purposes. On the other hand, if the proposition to deepen the canal should not be approved the question would still remain whether such a dam might not be desirable for the purpose of regulating the river and increasing the water power thereon.

In order to complete the preliminary investigations relative to the proposed Genesee storage, Governor Morton, in 1896, approved an additional appropriation, which was expended during the summer of that year in completing the additional surveys. To the present time the State has expended on preliminary investigation of the Genesee storage project the following amounts: In 1890, $3,000; in 1892, $7,000; in 1893, $10,000; in 1896, $10,000; in all, $30,000. As a result of this expenditure complete plans and specifications have been prepared as shown in the Annual Report of the State Engineer and Surveyor for 1896.[1]

INTERESTS TO BE SERVED.

The following are the interests to be served by the construction of these extensive storage works on Genesee River:

(1) The flow of the river would be regulated, thus effectually preventing in the future the devastating floods which occurred in 1815, 1835, 1857, 1865, 1889, 1893, 1894, and 1896. The floods in the years just

[1] By way of presenting a full list of the work on the Genesee storage, reference may be made to the special report of John Bogart, State engineer and surveyor, in Appendix F of the Annual Report of the State Engineer and Surveyor for the fiscal year ending September 30, 1890. The reports of Messrs. Bailey and Kibbe, assistant engineers to Mr. Bogart, are covered by the same reference. The report of Martin Schenck, State engineer and surveyor, may be found at page 44 of the Annual Report of the State Engineer and Surveyor for the fiscal year ending September 30, 1893. The report of E. Sweet, ex-State engineer and surveyor, as consulting engineer, may be found in Appendix H of the Annual Report of the State Engineer and Surveyor for the fiscal year ending September 30, 1893. The report of the commissioners appointed in 1892 by Governor Flower may be found in Senate Doc. No. 23, 1893. The first report of the writer may be found in Appendix G of the Annual Report of the State Engineer and Surveyor for the fiscal year ending September 30, 1893. The second report may be found in Appendix E of the Annual Report of the State Engineer and Surveyor for the fiscal year ending September 30, 1894. The work done in 1896 is described at length in the Annual Report of the State Engineer and Surveyor for the fiscal year ending September 30, 1896. See also a paper by the writer, The Genesee River storage and its relations to the Erie Canal and the manufacturing interests of western New York, prepared for the Rochester Chamber of Commerce. This paper contains large amount of historical information not given in the official reports. Governor Morton's veto may be found in the Governor's State Papers for 1895.

enumerated were especially severe, but floods not so severe, yet doing considerable damage, have occurred in several of the intervening years. The most severe flood was that of 1865, which destroyed fully $1,000,000 worth of property in the city of Rochester.

(2) Water would be supplied for the enlarged Erie Canal. According to Mr. Bogart's report of 1890, there should have been provided a storage on Genesee River of 1,500,000,000 cubic feet for the purpose of supplying Erie Canal as it existed at that date. Estimates made in 1896 show that for the purpose of fully supplying the enlarged canal, as now in process, there should be made a storage on Genesee River of 2,500,000,000 cubic feet.

(3) The agricultural production of the broad level area included in Genesee Valley between Rochester, Mount Morris, and Dansville, estimated at from 60 to 80 square miles, might be greatly increased by moderate irrigation if the flood contingency was removed and the proper irrigation channels were constructed.

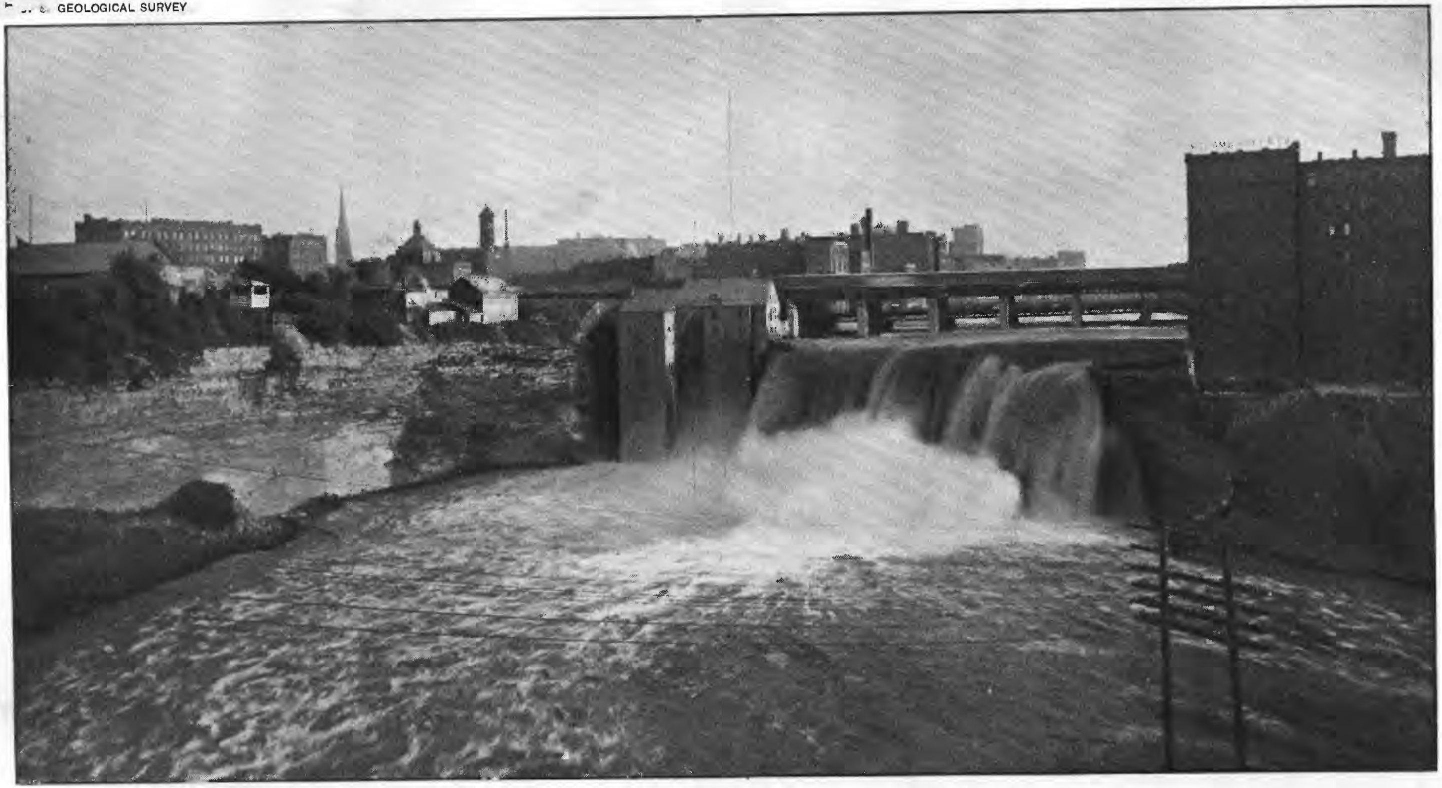
(4) Considerable sanitary benefit to this section would result from the increased flow during the low-water period through the proposed regulation. The entire sewage at Rochester, a city of 160,000 inhabitants, now passes into Genesee River. The channel of this stream, between the foot of Lower Falls at Rochester and Lake Ontario, is so broad and deep that during the time of extreme low water in the summer and fall the current is scarcely perceptible. The sewage of the city therefore lodges in this section, producing a serious nuisance. The regulation of the river, by preventing floods, would also improve the sanitary condition of the broad upper valley, where the annual overflow has been shown to cause more or less sickness.

(5) The water power would be increased. Wheels are now set on Genesee River capable of producing, at the manufacturers' rating, 19,178 horsepower, while the low-water flow of the stream does not exceed about 6,000 horsepower. The regulation as finally proposed would produce much more power than this.

In summation of the preceding points it may be urged, in general, that in constructing the proposed Genesee storage dam, in addition to the private interests to be conserved, public service of an extended character would be performed.

INVESTIGATION OF THE FLOOD OF 1865.

The great flood of March, 1865, worked such destruction that the legislature, on May 1 of that year, passed an act appointing commissioners to ascertain the cause of the inundation of the city of Rochester, what obstructions, if any, had been placed in the river, and what measures, proceedings, and remedies were necessary to guard against the recurrence of such an inundation. The commissioners appointed under this act examined carefully the evidence as to the flood, and arrived at the conclusion that there were three principal causes:



UPPER FALL OF GENESEE RIVER AT ROCHESTER, NEW YORK, AT TIME OF FLOOD

(1) The sudden melting of an immense body of snow which had accumulated during the previous winter.

(2) Obstructions caused by the bridge and embankment of what is now the New York, Lake Erie and Western Railway at Avon. The openings at this place are stated to have been adequate for ordinary floods, but entirely too small for the quantity flowing in March, 1865. Hence, at the time of greatest flow, the water stood three feet higher on the upper side of the embankment than on the lower side. The embankment finally gave way, thus allowing a large quantity of ponded water to flow suddenly down the river, filling the channel at Rochester beyond its carrying capacity.

(3) Obstruction of the channel of the river through the city of Rochester in such manner as to cause overflows into the Erie and Genesee Valley canals at that place. The commissioners also point out that the construction of the Erie Canal aqueduct is such as materially to increase the obstruction at Rochester.

From the best available figures the maximum flow at Rochester in the great flood of March, 1865, probably did not exceed about 40,000 cubic feet per second. The danger limit is reached when the flow at that place approximates 33,000 cubic feet per second.

The following are the openings of the several bridges, etc., spanning Erie Canal in the city of Rochester, as they exist at present: Court street bridge, 5,081 square feet; Main street, 3,367 square feet; Andrews street, 4,511 square feet; Central avenue, 4,450 square feet; Erie Canal aqueduct, 4,308 square feet.

As a chief cause of the 1865 flood the commissioners considered that cutting off the forests and clearing lands were likely to lead to heavier floods from year to year. In view, therefore, of what seemed to the commissioners a constant source of danger, they arrived at the conclusion that a much larger waterway through the city of Rochester was imperative. It may be here remarked that the waterway at Rochester is still substantially the same as in 1865; if anything, it has been somewhat contracted by various constructions since that date.[1]

MOUNT MORRIS SITES.

Referring to Mr. Bogart's report of 1890, it is learned that the investigations of that year were general in their character. The work was carried on more particularly with reference to a location in Genesee River gorge, between Mount Morris and the foot of the Portage Falls. No detailed surveys were made further than necessary to make a general estimate of the cost of a dam 58 feet in height, which would store 1,500,000,000 cubic feet, the amount considered necessary for canal purposes alone. Such a dam, Mr. Bogart estimates, could be erected for about $1,000,000.

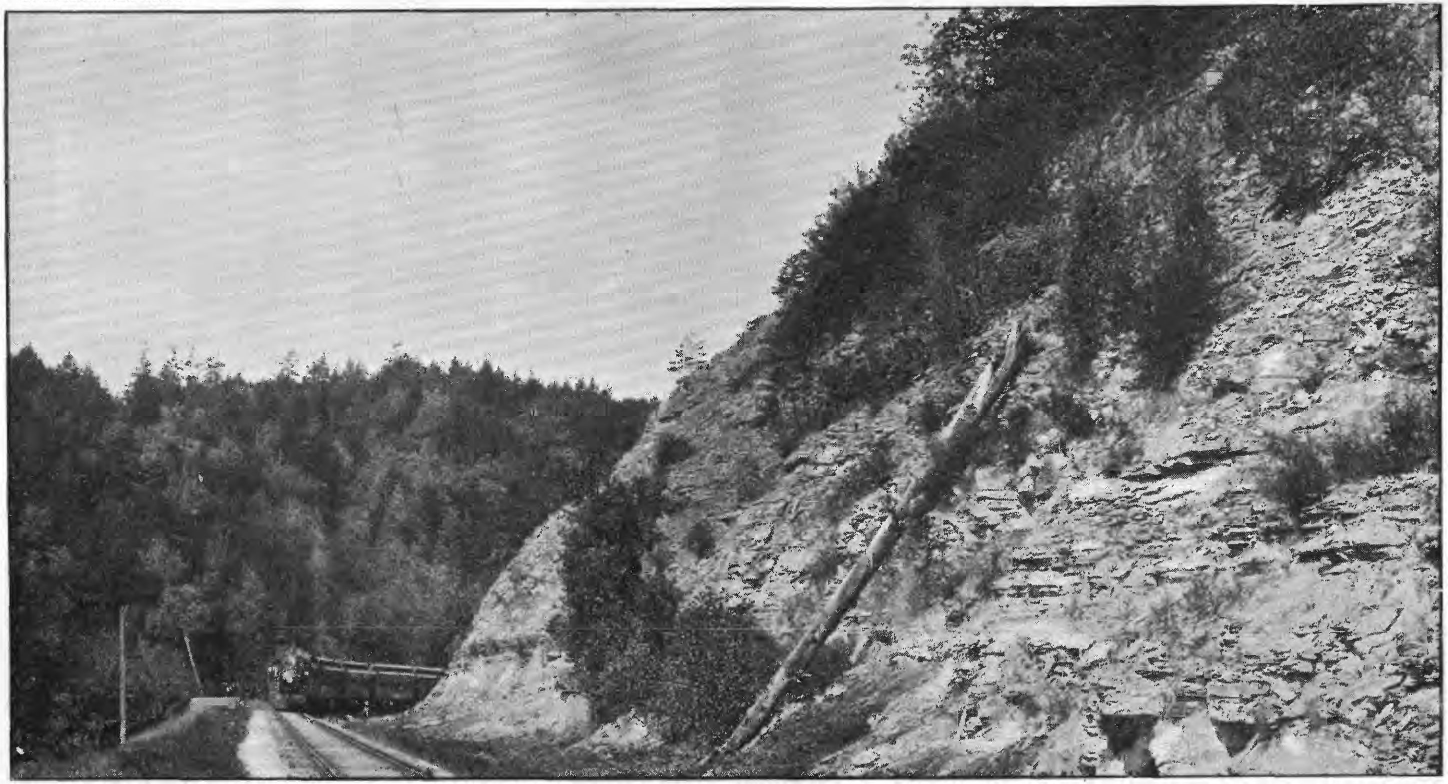
[1] For report of the commissioners appointed to investigate the causes of the inundation of the city of Rochester in March, 1865, see Ass. Doc. No. 117 (1866).

The work performed under the direction of the author, in 1893, was of an entirely different character. The report of 1890 having indicated the Mount Morris Canyon as a desirable location, with a number of sites pointed out, of which general investigations had been made, it became desirable to investigate those sites in detail and to prepare close estimates of the cost of constructing dams at each. Detailed investigations were accordingly made of the three sites favorably reported upon in 1890, the results of which may be found in the Annual Reports of the State Engineer and Surveyor for 1893 and 1894, where estimates of the cost of the several dams are also given in detail. Referring to the estimates, it appears that at site No. 1, in Mount Morris Canyon, a dam raising the water surface 130 feet would cost, if built of concrete alone, $2,450,000, but if built with sandstone faces throughout, except for the spillway, where granite is provided, the estimated cost would become $2,590,000. A dam of the same height at site No. 2, if built throughout of concrete, would cost $2,600,000, but with sandstone faces and independent spillway the cost would be $2,720,500, or, with roadway, $2,785,000.

In regard to the total storage to be obtained in Mount Morris Canyon the following are the figures at sites Nos. 1 and 2, the two sites chiefly considered: At site No. 1 a dam 130 feet in height will store 7,700,-000,000 cubic feet, and at site No. 2 a dam of the same height will store 7,040,000,000 cubic feet. Since no conclusion has been reached as to which of these sites to adopt, for the purposes of comparison a mean of 7,370,000,000 cubic feet has been taken as the approximate available storage, and the mean of $2,785,000 as the approximate total cost. On this basis the estimated cost of this storage becomes $377.88 per million cubic feet stored.

PORTAGE SITE.

As already stated, the investigations of the Genesee River storage project were finally completed in 1896. In that year detailed surveys were made of a new site known as Portage site (shown on Pl. II), the proposed dam to be located at Portage, about 1,400 feet above the Erie Railway bridge, at a point where the gorge presents extremely favorable conditions for the erection of a high dam. At this place solid rock exists immediately in the bed of the river, with only a couple of feet of water flowing over it, and also extends high up on the bluffs at either side, whereas at all of the sites in the gorge near Mount Morris the rock was only found at from 15 to 20 feet below the water surface and of such an open texture as to require cut-off trenches about 30 feet deep, or to a total depth of nearly 50 feet below the water. The proposed Portage dam is also 500 feet vertically above the previously mentioned dam site, thus rendering that additional number of feet available for power purposes—a fact which



EAST SIDE OF GENESEE GORGE AT SITE OF PROPOSED PORTAGE DAM places a materially different aspect on the commercial side of the Genesee River storage project.

A short distance above the proposed Portage site the upper Genesee Valley broadens out to a width in places of from one to two miles, although the general width of the valley does not exceed, for several miles in extent longitudinally, about one mile. It narrows in two or three places to a less width than this. The valley is now a good agricultural region, in a fair state of cultivation, and presents, on the whole, as favorable conditions for farming as any similar valley in the State. The Western New York and Pennsylvania Railway passes through the middle of the valley on the line of the abandoned Genesee Valley Canal. Along the line of this railway the villages of Portageville, Rossburg, Wiscoy, and Fillmore are situated. The reservoir project includes the relaying of the railway above the flow line on the west side of the valley, as well as the removal of the villages named. The total area below the flow line is 12.4 square miles and the entire area proposed to be taken for reservoir purposes, including a strip 10 feet vertically above the flow line, is 13.7 square miles. The project also includes the removal of several cemeteries, the building of highway bridges across the reservoir, and the construction of a roadway entirely around the same.

Without having made a detailed canvass, it is estimated that the present population of the proposed Portage reservoir site, in the villages and on the farms, is about 1,200. In reference to dispossessing this number of people of their homes for the purpose of creating a large storage reservoir, it may be said that such a proceeding is not only not uncommon in this State, but that the population to be removed in the case of the new Croton reservoir is far greater than at the Portage reservoir. According to maps furnished by the Croton water department, it appears that the new Croton reservoir includes the taking of either the whole or parts of something like three large villages and nine or ten hamlets. The total population to be removed from the submerged area of the new Croton reservoir is not given, but actual inspection of maps of the proposed sites indicates that it must be several times larger than the number to be dispossessed at Portage. The villages of Katonah, Purdy Station, and Croton Falls are much larger than any of the villages in the Portage reservoir site. The main line of the New York and Northern Railroad passes for several miles through the valley and requires relocating above the flow line, the same as is proposed for the Western New York and Pennsylvania Railway along the Portage reservoir. It appears, therefore, that the city of New York is now doing under State laws everything in the way of so-called radical change which it is proposed to do at Portage. In both cases the sufficient reason for these changes may be found in the better meeting of public necessities.

The estimated cost of the proposed Portage reservoir, including land damages, dam, reconstruction of railway, removal of cemeteries, the cutting of all timber within the drainage areas, the construction of highway bridges, etc., is $2,600,000, the storage to be provided by this expenditure amounting to 15,000,000,000 cubic feet; at this rate the cost per million cubic feet stored is $173.33. The main characteristics of the proposed reservoir are shown by the following table, condensed from pages 708 and 709 of the report of the State Engineer and Surveyor of New York for 1896:

Capacity of proposed Portage reservoir.

Elevation of water surface above sea level.	Area of water surface.	Total volume of water in reservoir.	Inches on water-shed.
Feet.	*Sq. miles.*	*Cubic feet.*	
1,100.0	0.2320	101,400,000	0.044
1,105.0	0.5330	217,623,000	0.094
1,110.0	0.8340	333,900,000	0.143
1,115.0	1.1350	450,100,000	0.194
1,120.0	1.4357	566,300,000	0.244
1,125.0	2.0659	942,100,000	0.406
1,130.0	2.6692	1,318,000,000	0.567
1,135.0	3.3264	1,694,000,000	0.729
1,140.0	3.9566	2,070,000,000	0.891
1,145.0	4.5255	2,780,000,000	1.196
1,150.0	5.0944	3,490,000,000	1.502
1,155.0	5.6633	4,200,000,000	1.808
1,160.0	6.2322	4,910,000,000	2.113
1,165.0	6.8293	5,945,000,000	2.559
1,170.0	7.4264	6,980,000,000	3.004
1,172.0	7.6652	7,395,000,000	3.182
1,173.0	7.7846	7,602,000,000	3.271
1,175.0	8.0235	8,016,000,000	3.451
1,180.0	8.6206	9,051,000,000	3.896
1,185.0	9.4362	10,366,000,000	4.462
1,190.0	10.2518	11,681,500,000	5.016
1,195.0	11.3007	13,257,000,000	5,710
1,200.0	12,3495	15,000,000,000	6.458

Comparing the foregoing statements of cost with those made on the preceding page with reference to the cost of the proposed reservoir in Mount Morris Canyon, it appears that at Portage a storage of 15,000,000,000 cubic feet can be made for somewhat less than the cost of 7,300,000,000 cubic feet at Mount Morris; or, as a general statement, we may say that a given expenditure at Portage produces double the storage that it will produce at Mount Morris. The Portage reservoir develops the full capacity of the drainage area for such a dry year as 1895. It is considered that this full development is necessary in order to obtain the most satisfactory results in river regulation.

As reasons in detail for preferring Portage site to that at Mount Morris, the following may be mentioned:

(1) The Portage site affords more water for a given expenditure.

(2) The Portage site is considered safer than the Mount Morris site. As shown in the Genesee Storage Reports of 1893–94, the shales at Mount Morris are open; and while it is, without doubt, possible to make a safe dam there, it would be at much greater cost than at Portage. In view of the large storage provided at either place, the dam must be absolutely safe, as its failure would work vast destruction.

(3) The material for the dam is nearly all on the ground at Portage, while at Mount Morris it needs to be brought from a distance.

(4) The Portage site affords greater water-power development. With the Genesee storage dam located at Mount Morris the total head on which the storage can be applied is 282 feet, while with a dam at Portage the total head on which the stored water may be applied is 782 feet.

(5) On account of great depth of foundation at Mount Morris, it would be necessary to expend over $1,000,000 before the dam could be brought to the level of the present water surface. The conditions are such that the floods of every spring would sweep over the work, obliterating all evidence that any money had been expended, which must necessarily continue for at least two or three years, until the foundations could be fully placed. At Portage, on the other hand, a good foundation is found near the water level. Indeed, the difference in cost of foundation is such that nearly the total expenditure at Mount Morris is for the dam, the flowage ground costing only $75,000, while at Portage the estimated cost of the dam is only $1,000,000, the balance of the expenditure there being for right of way, change of railway line, etc.

The proposed regulation of Genesee River has been computed on the basis of a minimum discharge of 300 cubic feet per second, in the case of a reservoir storing 7,500,000,000 cubic feet, and also on a basis of 457 cubic feet per second in the case of a reservoir storing 15,000,000,000 cubic feet. As to the reason for fixing upon these minimums, it may be remarked that in river regulation the outflow from the storage reservoir should be so arranged as to make the benefit to all parts of the stream equal. Especially is this proposition true when, as in the present case, there is water power distributed throughout the whole extent of the stream below the storage point. Obviously the way to do this is to plan for an outflow proportional to the drainage area. In the present case we have a drainage area at Rochester of 2,365 square miles, and one of 1,000 square miles above Portage, or the area above Rochester is about 2½ times the area above Portage. The minimum regulated flow at Rochester may justly be made 2.365 times the assumed minimum flow at Portage.

Assuming 680 cubic feet per second as the flow below which the stream will never be allowed to fall at Rochester, we have for a reservoir storing 7,500,000,000 cubic feet a corresponding minimum outflow from the reservoir of 300 cubic feet per second, or for a storage of 15,000,000,000 cubic feet an outflow of 457 cubic feet per second, the latter figure being arrived at by assuming the maintenance of a minimum flow at Rochester of at least 1,080 cubic feet per second. The computations of the tables on pages 119 to 121 are carried out on this basis. The regulated flows for the month of May are greater than for the other months. They are also greatest during the months of canal navigation, the addition being made in order to provide for the quantity of water to be taken for the enlarged Erie Canal, which quantity has been fixed at 80 cubic feet per second for every month of the navigation season except May, and at 177 cubic feet per second for that month, the excess quantity for the month of May being required in order to provide for filling the canal at the beginning of the month.

The first table shows the effect on the flow of Genesee River from June, 1894, to November, 1896, inclusive, as influenced by the storage at Portage of 7,500,000,000 cubic feet of water, provided at least 300 cubic feet per second is allowed to flow continually at Portage, and at least 600 cubic feet per second is always flowing at Rochester in addition to the amount required for canal purposes. The figures given in the left-hand column show the proposed minimum flow at Rochester, this being the 600 second-feet above noted, together with 80 second-feet for the canal for the months from June to November, inclusive, and 177 second-feet for the month of May. The next two columns give the discharges at Rochester and Portage under natural conditions. The fourth column is the difference between these, or the quantity of water entering the river below Portage, and next to this is the minimum amount to be added at Portage in order to maintain the proposed minimum flow at Rochester of 600 cubic feet per second, not including the amount taken by the canal. The quantity available at Rochester for power purposes is shown in the next column, and is obtained by adding the flow at Rochester, less the flow at Portage, to the actual flow from Portage reservoir and the surplus flowing over the spillway at Portage reservoir, and then deducting the quantity taken by the canal.

Regulation of Genesee River by storage at Portage.

[With storage of 7,500,000,000 cubic feet at Portage and flow of at least 600 second-feet at Rochester.]

Month.	Proposed minimum flow at Rochester.	Natural flow at Rochester.	Natural flow at Portage.	Flow at Rochester less flow at Portage.	Minimum amount to be added at Portage.	Available at Rochester.	Actual flow from Portage reservoir.	Surplus flowing over spillway.
1894.	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*
June	680	2,321	981	1,340	....	2,205	300	645
July	680	292	123	169	511	600	511	....
August	680	442	187	255	425	600	425	....
September	680	1,963	830	1,133	....	1,353	300	....
October	680	899	380	519	161	739	300	....
November	680	1,729	731	998	....	1,505	300	287
December	600	1,256	531	725	....	1,241	300	216
1895.								
January	600	1,335	565	770	....	1,330	300	260
February	600	495	209	286	314	600	314	....
March	600	3,985	1,684	2,301	....	3,867	300	1,266
April	600	4,257	1,800	2,457	....	4,197	300	1,440
May	777	385	163	222	555	600	555	....
June	680	283	120	163	517	600	517	....
July	680	232	98	134	546	600	546	....
August	680	254	108	146	534	600	534	....
September	680	221	93	128	552	600	552	....
October	680	230	97	133	547	600	547	....
November	680	993	420	573	107	793	300	....
December	600	2,710	1,146	1,564	....	1,864	300	....
1896.								
January	600	964	408	556	44	856	300	....
February	600	2,005	848	1,157	....	1,457	300	....
March	600	6,158	2,604	3,554	....	4,999	300	1,145
April	600	7,172	3,033	4,139	....	7,155	300	2,716
May	777	347	147	200	577	600	577	....
June	680	654	277	377	303	600	303	....
July	680	501	211	290	390	600	390	....
August	680	416	176	240	440	600	440	....
September	680	327	138	189	491	600	491	....
October	680	3,667	1,556	2,111	....	2,331	300	....
November	680	1,728	731	997	....	1,486	300	269

The actual flow from Portage reservoir is taken to be the minimum of 300 cubic feet per second ordinarily assumed, plus the amount necessary to make up the deficiency in the quantity of water entering the river at points between Portage and Rochester. The last column that on the right-hand side, shows the surplus flowing over the spillway at Portage reservoir during the comparatively few months when the natural flow has filled the reservoir, supplied all demands of evaporation from the surface, and still is in excess.

The next table exhibits the condition of the reservoir from month to month under the above conditions. The figures are given not in cubic contents but in equivalent depth in inches on the total tributary watershed of 1,000 square miles. The reservoir is assumed to be full at the beginning and end of June, 1894, the total storage of the reservoir being equivalent to 3.23 inches in depth on the watershed. The total waste from June 1, 1894, to December 1, 1896, equals, under the conditions of this table, 9.36 inches on the watershed.

Flow into and from Portage reservoir under the conditions assumed.

[In inches on watershed.]

Month.	Inflow to reservoir.	Outgo from reservoir.			Excess.	Deficiency.	In reservoir at end of month.	Wasted.
		Evaporation.	Amount to stream.	Total outgo.				
1894.								
June	1.10	0.03	0.33	0.36			3.72	0.72
July	.14	.04	.59	.63		0.49	2.76	
August	.22	.04	.49	.53		.31	2.45	
September	.93	.03	.33	.36	0.57		3.02	
October	.44	.02	.35	.37	.07		3.09	
November	.82	.01	.33	.34	.48		3.25	.32
December	.61	.01	.35	.36	.25		3.25	.25
1895.								
January	.66	.01	.35	.36	.30		3.25	.30
February	.22	.01	.33	.34		.12	3.13	
March	1.94	.01	.35	.36	1.58		3.25	1.46
April	2.01	.02	.33	.35	1.66		3.25	1.66
May	.19	.04	.64	.68		.49	2.76	
June	.13	.04	.58	.62		.49	2.27	
July	.11	.03	.63	.66		.55	1.72	
August	.12	.03	.61	.64		.52	1.20	
September	.10	.02	.62	.64		.54	.66	
October	.11	.01	.61	.62		.51	.15	
November	.47	.01	.33	.34	.13		.28	
December	1.32	.01	.35	.36	.96		1.24	

Flow into and from Portage reservoir under the conditions assumed—Cont'd.

[In inches on watershed.]

Month.	Inflow to reservoir.	Outgo from reservoir.			Excess.	Deficiency.	In reservoir at end of month.	Wasted.
		Evaporation.	Amount to stream.	Total outgo.				
1896.								
January	.47	.01	.35	.36	.11		1.35	
February	.91	.01	.32	.33	.58		1.93	
March	3.00	.01	.35	.36	2.64		3.25	1.32
April	3.38	.02	.33	.35	3.03		3.25	3.03
May	.17	.03	.67	.70		.53	2.72	
June	.39	.04	.34	.38	.01		2.73	
July	.24	.04	.45	.49		.25	2.48	
August	.20	.04	.51	.55		.35	2.13	
September	.16	.02	.57	.59		.43	1.70	
October	1.74	.02	.35	.37	1.37		3.07	
November	.82	.01	.33	.34	.48		3.25	.30

Similar tables might be given, showing the regulation of the river as affected by the storage at Portage of 15,000,000,000 cubic feet of water for the same period, with at least 457 cubic feet per second always flowing at Portage, and at least 1,000 cubic feet per second at Rochester, in addition to the amount required for the canal. The chief difference is that during only three months of this period would there be any overflow through the spillway, the total waste equaling 2.11 inches. This would be in June, 1894, 521 second-feet; in April, 1895, 1,058 second-feet; in April, 1896, 350 second-feet. The amount at Rochester under the same conditions would be in no case below 1,000 second-feet.

It may here be pointed out that had the enlarged canal been in operation in July, 1894, and taking the estimated quantity of 80 cubic feet of water per second from Genesee River, the amount of water going to the canal would have been 27.4 per cent of the total flow of the river for that month; in August 18.1 per cent; in May, 1895, 46 per cent; in June, 28.3 per cent; in July, 34.5 per cent; in August, 31.5 per cent; in September, 36.2 per cent; and in October, 34.8 per cent. In May, 1896, the canal would have taken 51.3 per cent of the total flow of the river for that month; in June, 12.2 per cent; in July, 15.9 per cent; in August, 19.2 per cent; and in September, 24.5 per cent. It appears, therefore, that the taking of 80 cubic feet per second from Genesee River for canal purposes is a very serious matter to the water power of the stream and is unjustifiable, unless it be clearly shown that the addition to the wealth of the State is greater than if the water were used for supplying power. The actual damage resulting from taking at times 50 per cent of the unregulated flow of the stream is about as follows: As shown on a previous page, the minimum flow of the river is capable of producing 6,727 gross horsepower, or, what is the same thing, assuming 75 per cent efficiency, 5,046 net horsepower. One-half of the low-water power may therefore be taken at 2,523 net horsepower.

So long as the possibility exists of a draft upon the river equal to one-half of its minimum flow, this 2,523 net horsepower is practically rendered useless to its owners by reason of the uncertainty as to the exact time of the draft, or if not rendered useless, is far less valuable than if it were absolutely permanent power. In enforcing this view it may be pointed out that Rochester is a manufacturing town, made up chiefly of establishments using comparatively small quantities of power at each place, but that the power must still be continuous every day; that is to say, it must be absolutely permanent power. So long, therefore, as one-half the total minimum power of the stream is subject to stoppage during any month, the manufacturers will preferably use steam power, on account of its permanency, even at considerably greater expense. Bearing on this view, the fact may be pointed out that the use of soft coal in Rochester for steam purposes is stated as 500,000 tons a year, which, at an average price of $2.40 per ton, amounts to the sum of $1,200,000 annually. It may be considered settled, therefore, that water power is valuable at Rochester, and that anything which tends to reduce the permanent power 50 per cent is a very serious matter to the manufacturers of the city.

COMPARISON OF MOUNT MORRIS AND PORTAGE SITES.

As a final point in the discussion of Genesee River storage, comparison will be made between the Mount Morris project, storing 7,370,000,000 cubic feet, at a cost of $2,785,000, and the Portage project, storing 15,000,000,000 cubic feet, at an estimated cost of $2,600,000, for the purpose of determining the relative commercial advantages.

With the reservoir at Mount Morris storing 7,370,000,000 cubic feet there is 282 feet fall, on which 7,370,000,000 cubic feet, less the quantity required for the canal, may be applied for power purposes. As already explained, the constant outflow from the reservoir would never be less than 300 cubic feet a second. Continuous power development under this plan would, therefore, be based on 300 cubic feet a second at Mount Morris, something more than this at Geneseo and York, and on 600 cubic feet a second at Rochester. On this basis of computation it appears that the total permanent, continuous power to be realized from a reservoir storing 7,370,000,000 cubic feet and located in the Mount Morris Gorge would be 18,327 gross horsepower.

In regard to the increase in water power, the effective value of the storage will be the amount of permanent power above the low-water power of the stream. As already stated, the total permanent power for the unregulated stream is 6,727 gross horsepower. The gain due to the storage is, therefore, 11,600 gross horsepower. Assuming a price of $10 per gross horsepower, we reach an annual return from the increased power of $116,000; but the Mount Morris reservoir is estimated to cost $2,785,000. If we assume the project carried out by a private company, with money at 5 per cent, the annual interest on the investment is $139,250—a sum $23,250 in excess of the probable annual income when all the power created shall have been brought into use; but there should be a sinking, maintenance, and repair fund of at least $25,000 a year, in order to repay the principal investment, which if taken into account increases the probable deficiency to $48,250 a year. It must be concluded, therefore, that with the present understanding as to the minimum run-off of Genesee River the project of a storage reservoir in Mount Morris Canyon, storing approximately 7,370,000,000 cubic feet of water, at a cost of $2,785,000, is commercially impracticable.

If we consider the Portage project in its financial aspects, where it is proposed to construct a reservoir storing 15,000,000,000 cubic feet of water, at a cost of $2,600,000, we reach the following results:

The total fall from just above the upper fall at Portage to the mean level of Lake Ontario is 785 feet, of which the greater portion is available for the development of water power. Without going into detail, we may place the permanent, continuous gross horsepower of the river, with a storage of 15,000,000,000 cubic feet at Portage, at the following figures:

Power of Genesee River after construction of reservoir at Portage.

	Gross horsepower.
Portage to Mount Morris	25,924
Mount Morris	835
Geneseo and York	624
Rochester	29,840
Total	57,223

Deducting from 57,223 gross horsepower the present permanent power of 6,727 gross horsepower, we have 50,496 gross horsepower as the net increase in the permanent water power of the stream due to the construction of the Portage reservoir. At $10 per gross horsepower, as before, the annual income when the power is utilized amounts to $504,960. The estimated cost of producing this vast increase in power is $2,600,000. Assuming an interest rate of 5 per cent, the annual interest is $130,000; adding to that amount $25,000 for sinking fund, maintenance, and repairs, the total annual expense becomes $155,000. The difference of $349,960 is the net annual income.

As already shown, when interest is taken into account, the Mount Morris project becomes commercially impracticable. The Portage project, on the other hand, shows an annual income, above interest account, sinking fund, maintenance, and repairs, of $349,950, which, capitalized at 5 per cent, represents $6,999,000. If we assume 4 per cent, the capitalization of the annual income may be expected ultimately to represent $8,748,750.

SUMMARY.

Lack of space prevents discussion in greater detail of the Genesee River storage project, and the following summation is presented as embodying the main points of the discussion:

(1) Of the several available sites for reservoirs on Genesee River that at Portage is preferable to others, because it affords the largest storage at the smallest cost per unit volume.

(2) Serious floods have occurred a number of times in Genesee River at Rochester, the most serious being that of March, 1865. At least $1,000,000 loss resulted from that flood. The flood in April, 1896, was nearly as severe as the flood of March, 1865, although, as the river channel was clear, very little damage ensued.

(3) As the result of three years' measurements of Genesee River, it is determined that the minimum flow of the stream may for the entire year be as low as 6.67 inches on the watershed.

(4) A study of existing conditions shows that the Genesee River drainage area has been nearly denuded of forests, and hence that severe spring floods are likely to be frequent. For the same reason the summer flow of the stream is less than formerly.

(5) As a tentative conclusion, based on the data at hand, it may be said that deforestation of a drainage area may tend not only to increase floods somewhat, but to decrease materially the amount of the annual run-off.

(6) A comparison of the conditions existing on the drainage area of Genesee River with those of the upper Hudson, which is still largely in forest, shows less run-off under given conditions from the Genesee than from the Hudson, thus indicating the probable effect of the forest in increasing the run-off.

(7) As regards the upper Genesee drainage area, the forest has been removed by landowners who have commercially profited by such romoval; the effect, however, has been to injure permanently every riparian owner on the stream; hence it is proper that the State should spend money either in partially reforesting the area or in constructing river regulation works. The latter is preferable, because the benefits can be realized in a few years. If the State does not desire to construct such works, there should be no obstacles interposed to their construction by a private company.

(8) The proposed Portage reservoir will impound 15,000,000,000 cubic feet of water, at an estimated cost of $2,600,000, or at a cost of $173.33 per million cubic feet stored. It affords a permanent, continuous power above the present low-water flow of the stream of 50,496 gross horsepower, while the reservoir at Mount Morris affords only 11,600 horsepower above the present low-water power of the stream.

(9) Based on manufacturers' ratings, the present total developed water power of Genesee River from Portage to Rochester, inclusive, is 19,178 net horsepower; or, basing the amount of water power on the manufacturers' ratings of water required, and assuming 75 per cent efficiency on the wheels, the total power is 17,248 net horsepower, of which 16,683 net horsepower is within the limits of the city of Rochester.

(10) The enlarged Erie Canal will require 80 cubic feet of water per second from Genesee River for every month of the navigation season except May, and in that month a mean of 177 cubic feet per second.

(11) The present extreme low-water power of Genesee River at Rochester is 5,046 net horsepower, of which one-half, or 2,523 net horsepower, will be rendered very much less valuable to its owners because of the taking for the enlarged Erie Canal of 80 cubic feet per second in every month of the navigation season and 177 cubic feet per second in May.

WATER STORAGE ON HUDSON RIVER.

As noted in Part I of this paper, on page 33, Hudson River is divided at the Troy dam into the upper or water-power section and the lower or tidal portion. The proposed reservoirs are, as a matter of course, in the upper section, that above Troy.

EARLY SURVEYS.

The project for constructing storage reservoirs on the upper Hudson has been agitated for many years, the first surveys for this purpose having been made in 1874. In that year Prof. F. N. Benedict conducted surveys, and in his report proposed an extensive system of reservoirs. The chief interest attaching to this report is the proposition on the part of Mr. Benedict to build storage reservoirs at Blue Mountain, Racket, Forked, Beach, and Long lakes, and divert the water stored on these several lakes from their natural drainage into Racket River, to the south, thus making them artificially tributary to Hudson River. In proposing this diversion, Mr. Benedict apparently assumed that the State, in its sovereign capacity, could divert waters from one drainage basin to another without regard to the rights or wishes of the riparian owners.

In addition to the lakes already enumerated, which are naturally tributary to Racket River, Mr. Benedict proposed to make reservoirs of the following lakes and ponds in the upper Hudson drainage area: Round Pond, Catlin Lake, Rich Lake, Harris Lake, Lake Henderson, Newcomb Lake, Lower Works reservoir, Chain Lakes, Goodenow Pond, Goodenow River reservoir, South Pond, Clear Pond, Slim Pond, Ackerman Pond, Perch Pond, Trout Pond, Lake Harkness, Shedd Lake, First Sergeant Pond, Third Sergeant Pond, Plumley

Pond, Moose Pond, and Cary Pond. The total storage to be furnished by the entire system of reservoirs is placed at 18,419,781,600 cubic feet. The total cost of the proposed reservoirs was placed by Mr. Benedict at about $265,000, or, including the diversion canal and improvements at Long Lake, at a total of about $460,000. The dams

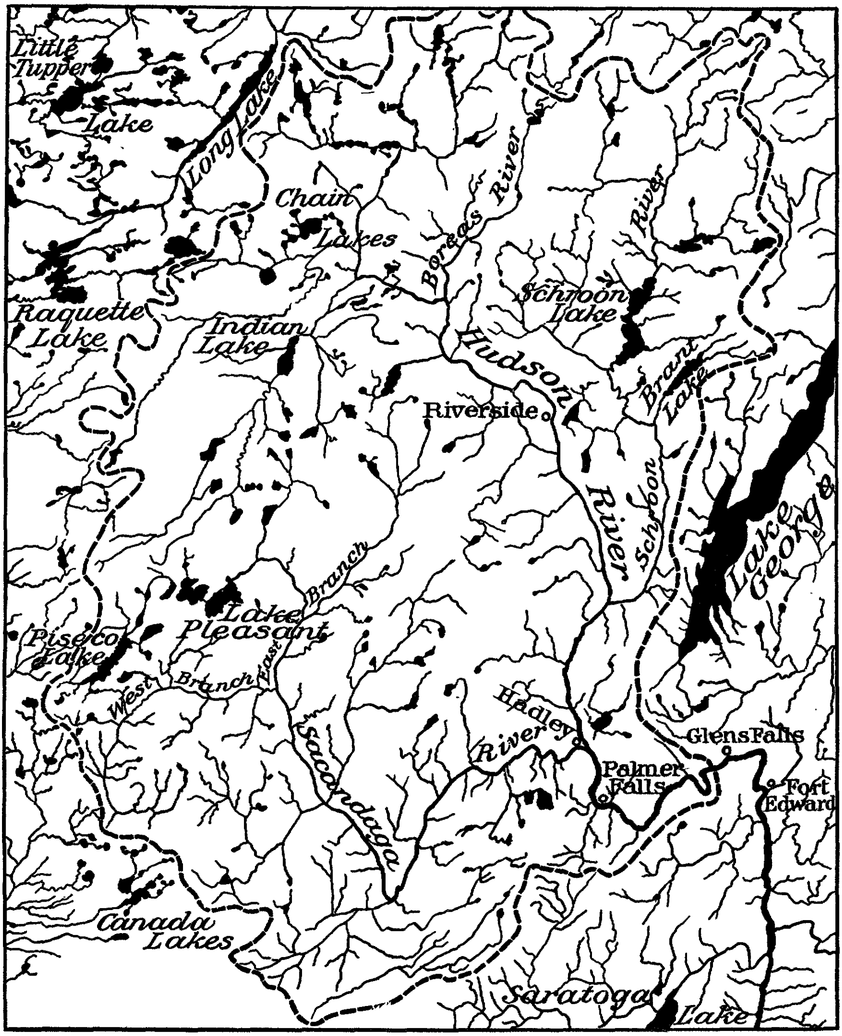


FIG. 1.—Map of drainage area of Hudson River above Glens Falls.

proposed were to be constructed of timber, very much after the plan of the timber dams still constructed by the lumbermen in this region, as shown on Pl. III.[1]

[1] For further particulars of Mr. Benedict's reservoir system, see Report on a Survey of the Waters of the Upper Hudson and Racket Rivers in the Summer of 1874, with Reference to Increasing the Supply of Water for the Chåmplain Canal and Improving the Navigation of the Hudson River, by F. N. Benedict, Ass. Docs. (1875), Vol. I, No. 6, p. 85.

A. LUMBERMAN'S DAM ON CEDAR RIVER

B. LUMBERMAN'S DAM ON INDIAN RIVER

In 1874, when Mr. Benedict prepared his report, the demands for water upon Hudson River were far less extensive than at present, and even in 1882 the total water power of the stream was, according to the statistics of the Report on the Water Power of the United States, Tenth Census, only 12,894 horsepower, while in 1895 the total horsepower was 43,481. Taking into account additional wheels set in the last two years, as well as the extensive development of the Hudson River Power Transmission Company now in progress 3 miles below Mechanicville, it is probable that early in 1898 there will be wheels set on Hudson River capable of furnishing, at full capacity, not far from 55,000 horsepower. This great development has led to a very strong demand in the last few years for increased flow during the low-water period.

RECENT INVESTIGATIONS.

In 1895 a survey of the upper Hudson Valley was authorized with the view of determining what lakes and streams may be improved, and the water stored and diverted, in order to provide for the enlargement of Champlain Canal; for restoring to the water of Hudson River at or below Glens Falls the water diverted therefrom for canal purposes, and for improving the navigation of the lower Hudson River. The Hudson River naturally divides into two sections—the upper and the lower—at the Troy dam, which is the head of the lower or tidal section. The proposed reservoirs are all in the upper section, above Troy.

When one considers the scope of the investigation it may be readily seen that the studies must necessarily be of rather wide range. Special consideration should be given the following topics:

(1) The area of the several subdivisions of the drainage area, together with the locations and extent of the reservoir sites, and the total area from which the run-off can be controlled.

(2) The rainfall and mean temperature of the tributary region, as well as its physical characteristics, the relative amounts of timber and cleared area, etc.

(3) The actual run-off of the stream from the known area for a series of years, and a deduction therefrom by comparison with the rainfall and temperature records of the amount which may be stored in the year of minimum rainfall; also the relation which the run-off in the year of minimum precipitation bears to what may be expected in the average year, and a deduction therefrom of the proper height of flow lines for full-capacity development.

(4) The areas of the reservoirs and the losses therefrom by evaporation which may be reasonably expected, with the amount of effective storage which may be gained by the reservoir system when developed to full capacity.

(5) The amount of water now diverted for the use of Champlain

Canal, and the amount to be diverted for such use when the enlargement is completed; also the proper method of managing the system of reservoirs in order to secure the best results to the canal, the navigable section, and the water power.

(6) The amount of water power now in use on the stream and the effect of the present and future diversion.

(7) The regimen of the tidal section, and the effect of the unregulated fresh-water flow and of the construction of the system of impounding reservoirs.

(8) The cost of the reservoirs and the relation which the actual cost bears to the amount of storage gained. This latter element determines the commercial feasibility of the project.

RESERVOIR SITES ON SACUNDAGA, MAIN HUDSON, AND SCHROON RIVERS.

The surveys, so far as carried, indicate that economical reservoirs controlling the entire drainage area to full capacity in the year of minimum rainfall may be constructed in the Sacundaga, main Hudson, and Schroon valleys, as shown in the following paragraphs.

The Sacundaga River has, as already stated, a total drainage area above its mouth at Hadley of 1,040 square miles. The catchment areas of reservoir sites on Sacundaga River, in square miles, are as follows:

Catchment areas of reservoir sites on Sacundaga River.

	Square miles.
Lakes Pleasant and Sacundaga	45
Piseco Lake	55
Arietta flow	40
Miscellaneous	50
Total	190

The main Hudson or North River has a total drainage area above Hadley, not including Schroon River, of 1,092 square miles. Of this area the portions shown below may be developed to full capacity in the year of minimum rainfall:

Catchment area of reservoir sites on main Hudson River.

	Square miles.
Thirteenth Pond	14
Chain Lakes	58
Catlin Lake	25
Lakes Rich, Harris, and Newcomb, and the Goodenow flow	83
Lake Henderson	18
Lake Sanford and the Tahawus flow	67
Boreas River and Boreas Pond	45
Cedar River	58
Indian Lake	146
Total	514

Schroon River has a total drainage area above its mouth of 550 square miles. The topography of the Schroon area is such as to admit of two distinct lines of treatment—either to construct one large dam at Tumblehead Falls, about a mile below South Horicon, or to construct a series of 16 to 18 small dams at various points in the area. In either case it is possible to control substantially the full flow of the 502 square miles above Tumblehead Falls, and the decision of which is better will turn chiefly on the question of relative cost, the estimate taking into account the fact that it will cost much more to operate a large number of reservoirs than to operate one.

Catchment area of small reservoirs on Schroon River.

	Square miles.
Minerva Brook at Olmsteadville	43.4
Hewett Pond	2.5
Loon Lake	11.6
Friend Lake	4.9
Elk Lake	15.9
Clear Pond	2.3
New Pond	1.7
Deadwater Pond	18.9
Hammond Pond	11.4
Dudley Pond	3.9
Overshot Pond	4.9
Paradox Lake	31.6
Paragon Lake	5.6
Crane Pond	7.2
Pharaoh Lake	8.3
Brant Lake	38.7
Valentine Pond	6.7
Schroon Lake at Starbuckville	259.2
Total	478.7

The area between Starbuckville and Tumblehead Falls not available with the system of small reservoirs is 23.3 square miles.

The total controllable area of the upper Hudson, with the system of small reservoirs in the Schroon Valley, is as follows:

Total catchment area of upper Hudson River.

	Square miles.
Sacundaga Valley	190
Hudson above Hadley	514
Schroon Valley	479
Total	1,183

With one large reservoir in Schroon Valley the catchment area is increased to 1,206 square miles.

The system of small reservoirs outlined in the foregoing is estimated to store 15,330,000,000 cubic feet, at a cost of $1,172,500; hence the cost per million cubic feet stored becomes $76.48. These figures, however, do not take into account the annual cost of maintenance and operation, which may be placed at $30,000 per year, and capitalized at 5 per cent is equivalent to a permanent investment of $600,000. Adding $600,000 to $1,172,500 gives a total permanent investment of $1,772,500.

A general estimate of the cost of the single large reservoir in Schroon Valley shows that with a dam at Tumblehead Falls 59 feet in height there would be impounded 15,925,000,000 cubic feet. The preliminary estimate indicates a total cost of $840,000, and a later survey indicates about $1,000,000. The final revision of the estimate on completion of the investigation may show a somewhat larger figure than this. Even if the cost were to be $1,100,000, it would still be exceedingly cheap storage, the cost for 15,925,000,000 cubic feet being on this basis only $69.14 per million cubic feet stored.

The dam at Tumblehead Falls would be located just below the outlet of Brant Lake, the elevation of the water surface of which is 801 feet. The flow line of the proposed reservoir has been placed at an elevation of 840 feet, thus giving a depth of 39 feet over the surface of Brant Lake, a depth of 33 feet over the surface of Schroon Lake, and a depth of 20 feet over Paradox Lake. With the reservoir full or nearly full, there would be continuous navigation from the head of Brant Lake to the head of Paradox Lake of about 35 miles. The villages of South Horicon, Bartonville, Starbuckville, and parts of Pottersville and Chester are within the flow line of this reservoir.

As another large reservoir to be built on the head waters of the Hudson, Indian Lake reservoir may be mentioned. As shown on page 128, the total controllable area at this lake is 146 square miles, which is capable of furnishing, in the year of minimum run-off, 4,468,000,000 cubic feet. To provide this storage, a dam raising the water surface 23 feet above the present dam is required. The storage of the present dam 10 feet in height is estimated at 800,000,000 cubic feet. In the spring of 1897 a private company, known as the Indian River Company, was organized to construct the Indian River reservoir. This company proposes to construct a masonry and concrete dam to the height of 23 feet above the old timber dam. The work is now in process of construction. The clearing of the margins of the lake includes the cutting of about 1,160 acres of timber.

The Indian River Company was the owner of considerable land bordering on and in the vicinity of Indian Lake. In consideration of the transfer of townships 15 and 32 of the Totten and Crossfield purchase to the State forest preserve board, that board has, in effect, purchased the dam in process of construction, which, with the clearing of the margins, is estimated to cost about $100,000. The forest preserve board stipulated that the superintendent of public works have the right to draw water from the reservoir when necessary for the supply of Champlain Canal, the balance of the storage to be used by the Indian River Company for increasing the low-water flow of Hudson River for the benefit of the water power. At a total cost of $100,000 the cost per million cubic feet stored becomes $22.38. Taking into account the quantity of water stored at Indian Lake, this must be considered a very cheap reservoir.[1]

Piseco Lake may also be referred to as another large reservoir which may be constructed on the upper Hudson at low cost. It is estimated that a storage of 1,725,000,000 cubic feet may be made, at an expenditure of $70,000, or at an average cost per million cubic feet stored of $40.

Without going further into detail, the following may be given as the approximate storage of the entire upper Hudson system, worked out to date.[2]

Approximate storage of upper Hudson River.

	Cubic feet.
Storage of Sacundaga and main Hudson River drainage areas, not including Boreas River reservoir, Boreas Pond, Indian Lake, and Piseco Lake	14,364,000,000
Boreas River reservoir and Boreas Pond	1,111,000,000
Indian Lake	4,468,000,000
Piseco Lake	1,725,000,000
Schroon Valley	15,925,000,000
Hadley	4,000,000,000
Conklinville	4,000,000,000
Total	45,593,000,000

This storage is considered sufficient, in conjunction with the natural flow of the unregulated portion of the river, to maintain at Mechanicville a flow of at least 4,500 cubic feet per second during the entire year.

In addition to the reservoirs named above, the general investigations indicate that there is, possibly, an opportunity to make a large reservoir on Sacundaga River by the erection of a dam about 20 feet in height at Conklinville, where there is a reach of river extending 24 miles to Northville. The available storage of such a reservoir is taken at about 4,000,000,000 cubic feet.

There is also an opportunity to construct on the main Hudson at Hadley, just above the mouth of the Sacundaga, another reservoir of about 4,000,000,000 cubic feet capacity, at a point where the natural conditions for constructing such a reservoir are considered very good. At the site of the proposed dam the river shows a granitic rock bottom

[1] This dam was completed in 1898.

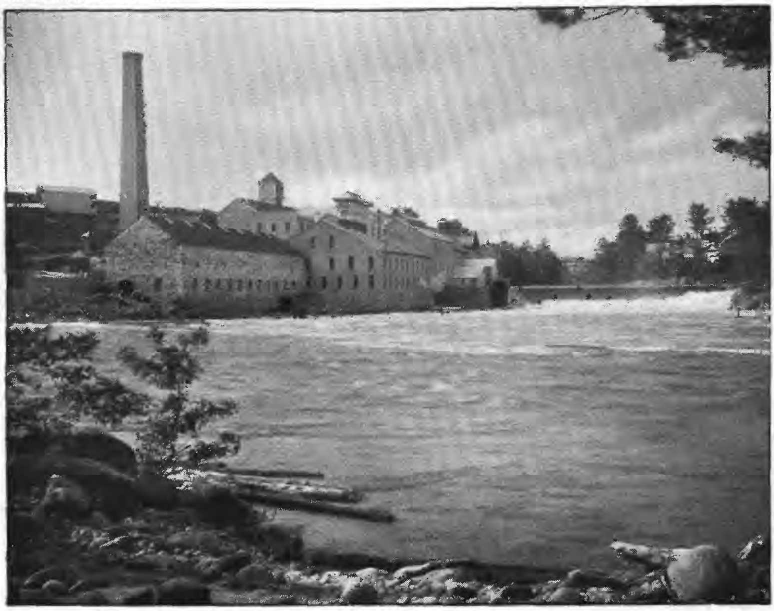
[2] For full details the reader is referred to the original reports on the upper Hudson storage surveys, in the Annual Reports of the State Engineer and Surveyor for the fiscal years ending September 30, 1895 and 1896.

with precipitous banks nearly 40 feet in height and about 100 feet apart. The material for a permanent stone dam exists in the vicinity, with an opportunity to construct a wasteway over natural rock at one side.

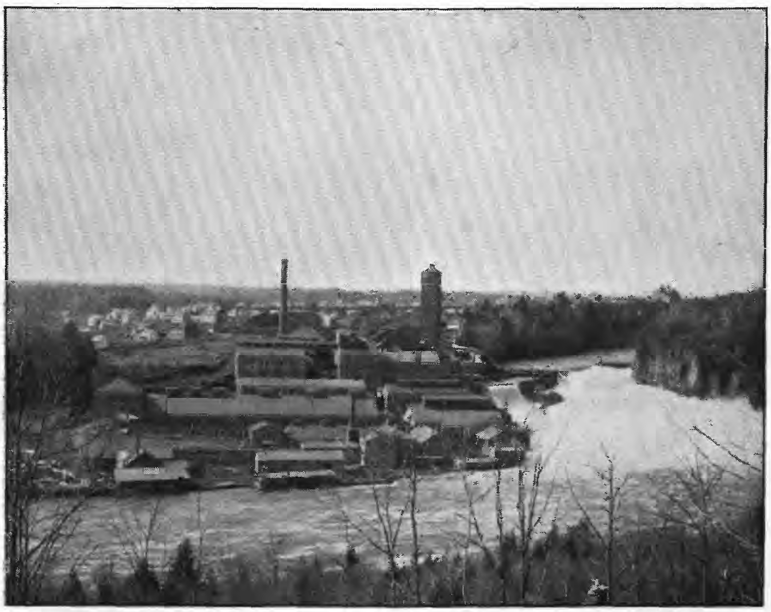
Inasmuch as all the storage except that of the Sacundaga area would pass through the Hadley reservoir, its construction would simplify the management of the system very greatly. In the summer season, as long as there is any storage above to be drawn upon, this reservoir could be kept nearly full and just the right quantity drawn out from day to day to keep the river at the assumed flow of 4,500 cubic feet a second at Mechanicville.

EFFECT OF PROPOSED STORAGE ON RIVER FLOW.

The foregoing quantities of storage have been fixed upon on the basis that the water yield of the year of minimum stream flow will furnish a storage of at least 12 inches, the flow line of the reservoirs themselves being located with reference to holding back 13.5 inches. If, however, one examines the tables of run-off of the Hudson at Mechanicville, given in Part I of this paper, on page 82, and of precipitation in the watershed, given on the next page, it is seen that much greater yields can be expected in an average year. From this point of view, it may be asked, Why not make the reservoirs somewhat larger than merely sufficient for the wants of the year of minimum flow and carry some water over from one year to another, thus more nearly attaining an absolute regulation of the river—not for a single year, but for a series of years? The chief objection to this method of procedure is that experience with other large reservoir systems is against other than a moderate development on this line, it having been repeatedly found that however high the flow line, reservoirs are likely to be nearly empty at the beginning of the storage period of the minimum year. Experience indicates that the rainfall and stream flow move in cycles, there being in each cycle several successive years of flow above the average. The demands for water tend to increase during the years of plenty, until those in charge apparently forget there will ever be a deficiency. The best practice, therefore, is to locate the flow line with reference to about the minimum yield, thus forcing an economy in the use of water from the beginning. By proceeding in this way provision may be made for carrying over moderate quantities of water from the latter end of the year more effectually than in any other way.



A. THE GEORGE WEST PAPER MILL, ON HUDSON RIVER AT HADLEY, NEW YORK.



B. THE HUDSON RIVER PULP AND PAPER COMPANY'S MILLS AT PALMER FALLS, ON HUDSON RIVER, NEW YORK.

Mean precipitation on the upper Hudson watershed.

[In inches.]

Month.	Albany.	Glens Falls.	Keene Valley.	Mean of Albany, Glens Falls, and Keene Valley.	Western Massachusetts.	Northern Plateau	Lowville Academy.	Johnstown Academy.	Cambridge Academy.	Fairfield Academy.	Granville Academy.	Mean of all.
December	2.71	3.19	2.75	3.01	4.31	3.57	2.14	2.91	2.36	2.78	2.48	2 92
January	2.75	3.16	3.00	3.03	3.36	3.88	2.35	3.30	3.36	2.69	2.08	2.99
February	2.49	3.03	2.22	2.64	2.83	3.60	2.43	2.86	2.61	2.06	1.42	2.56
March	2.72	2.72	2.24	2.50	2.94	2.52	1.78	3.63	2.12	2.36	1.74	2.48
April	2.80	2.15	2.09	2.14	2.02	2.39	1.91	2.93	.3.36	2.53	2.13	2.43
May	3.62	3.10	3.05	3.14	3.17	4 46	2.79	3.45	3.65	3.04	3.47	3.38
	17.09	*17.35*	*15.35*	*16.47*	*18.63*	*20.42*	*13.40*	*19.08*	*17.46*	*15.46*	*13.32*	*16:76*
June	4.07	2.83	2.89	2.99	3.24	3.88	3.42	4.20	4.66	4.29	3.21	3.67
July	4.29	3.25	3.61	3.53	3.44	3.83	3.67	4.01	3.91	4.21	3.63	3.78
August	3.96	4.17	4.21	4.20	3.91	5.07	2.85	3.14	3.98	3.66	2.97	3.79
	12.32	*10.25*	*10.71*	*10.75*	*10.59*	*12.78*	*9.94*	*11.35*	*12.55*	*12.16*	*9.81*	*11.25*
September	3.43	2.96	3.00	3.13	3.51	3.57	2.84	2.87	3.27	3.08	2.67	3.12
October	3.58	2.36	2.49	2.60	3.41	3.06	3.29	3.20	3.60	3.56	2.90	3.15
November	3.08	3.24	3.56	3.26	2.84	3.46	2.94	3.33	3.29	2.46	2.88	3 11
	10.09	*8.56*	*9.05*	*8.99*	*9.76*	*10.09*	*9.07*	*9.49*	*10.16*	*9.11*	*8.45*	*9.38*
Total	39.50	36.16	35.11	36.22	38.98	43.29	32.41	39.92	40.17	36.73	31.58	37.39

The figures in the above table are obtained by averaging the results obtained at Albany from 1825 to 1895; at Glens Falls, from 1879 to 1895; at Keene Valley, from 1879 to 1895; in western Massachusetts, from 1887 to 1895; in Northern Plateau, from 1889 to 1895; at Lowville Academy, from 1827 to 1848; at Johnstown Academy, from 1828 to 1845; at Cambridge Academy, from 1827 to 1839; at Fairfield Academy, from 1828 to 1849; at Granville Academy, from 1835 to 1849; the mean of Albany, Glens Falls, and Keene Valley, from 1879 to 1895. Although the foregoing figures are here given in detail, later studies indicate that the mean rainfall of the Northern Plateau as defined by the State meteorological bureau is the best rainfall record to apply to the upper Hudson area.

The proposed regulation of Hudson River, as thus far planned, is to be arranged on the basis of maintaining a flow of at least 4,500 cubic feet per second at Mechanicville, where, as has been seen, the drainage area is 4,500 square miles, such a regulation being equivalent to producing at Mechanicville a constant flow of 1 second-foot per square mile. The relation of such regulated flow to the natural unregulated flow may be seen by studying the diagrams of flow of Hudson River at Mechanicville given in Part I, on page 81.

As regards the change in the regimen of the stream due to storage, it may be remarked that the reservoirs have been designed on the basis of giving to the stream at least 0.5 inch on the drainage area per month. This amounts to 0.45 cubic foot per second per square mile for a month of thirty days; it is not, however, intended to state that the entire river will ever be as low as 0.45 cubic foot per second per square mile, or, what is the same thing, as low as 2,025 cubic feet per second at Mechanicville, but only that those tributary streams on which the storage reservoirs are located may be down to this figure. With 0.45

cubic foot per second per square mile always flowing away from the controlled drainage area, the natural flow of the unregulated portion will usually furnish an additional amount sufficient to keep the river, during the storge period, up to nearly the assumed 4,500 cubic feet at Mechanicville; or in case of extreme low water in winter other reservoirs may be relied upon to assist in the manner already pointed out.

On the basis of 12 to 14 inches available storage, there may be, with 0.5 inch per month always going to the stream, a possible total requirement for the year of from 15 to 18 inches.

The table in Part I of this paper, on page 82, shows that the total flow for the water year 1895 was only 17.46 inches, or in that year there might have been a shortage if the reservoir system had been in operation of perhaps 0.5 inch. Any such shortage would necessarily have been carried over from the year 1894, when, in November, there was a run-off of 1.58 inches. Allowing 0.5 inch to the stream, from the November rainfall alone there would have been 1.08 inches remaining in the reservoirs to be carried over to 1895.

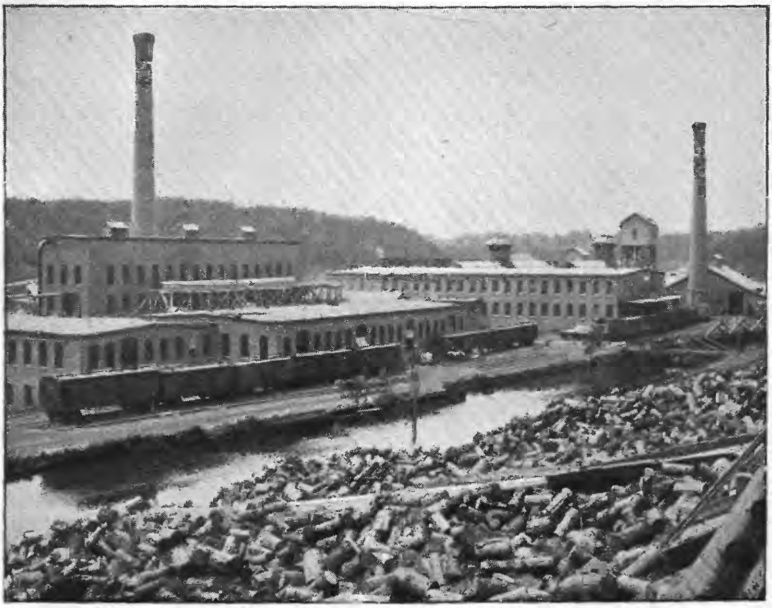
SUMMARY.

In conclusion, it may be said that it is entirely feasible to construct a system of reservoirs in the upper Hudson Valley, and such system may be designed with reference to the full capacity storage of at least 1,300 square miles of area, or 47 per cent of the total area above Glens Falls. Such control would result in the material reduction of floods at Glens Falls and other points.

The proposed total storage of 45,593,000,000 cubic feet would maintain 4,500 cubic feet per second flow, as well as supply the other necessary demands, in the driest season of the gaging period. The discharge measurements show that whereas the minimum unregulated flow at Glens Falls is as low as 900 cubic feet per second for a monthly mean, with the storage carried out, the probable monthly mean flow at Glens Falls will be at least 3,000 to 3,600 cubic feet per second. The minimum regulated flow of 4,500 cubic feet per second at Mechanicville will increase the low-water depth in Hudson River at Albany about 1.5 feet.

The diversion of water for the use of Champlain Canal is an injury to the water power at Glens Falls and lower points on the river. Since water power is much cheaper than steam power, the taking of the water of the river away from the manufacturers is a serious matter. In the fourteen years from 1882 to 1895 the use of water power on Hudson River has increased from a total of 12,894 net horsepower in 1882 to 43,481 net horsepower in 1895, an increase of 237 per cent.

The upper Hudson storage system is estimated to cost from $60 to $70 per million cubic feet stored, a sum considerably less than the cost of many other systems.



A. GLENS FALLS PAPER MILLS AT FORT EDWARD, NEW YORK.

B. DAM OF THE HUDSON RIVER POWER TRANSMISSION COMPANY DURING CONSTRUCTION, OCTOBER, 1897.

DEVELOPMENT OF WATER POWERS.

POWER DEVELOPMENT AT NIAGARA FALLS.

The possibility of water-power development at Niagara Falls has attracted attention for many years, the first utilization there having been made in 1725, when the French erected a sawmill near the point where the Pittsburg Reduction Company's upper works now stand for the purpose of supplying lumber for Fort Niagara. Between 1725 and the early years of the present century little is known of the use made of Niagara Falls power further than that sawmills were in operation there during the whole period. In 1805, however, Augustus Porter built a sawmill on the rapids, and in 1807 Porter & Barton erected a gristmill. In 1817 John Witmer built another sawmill at Gill Creek, and in 1822 Augustus Porter built a gristmill along the rapids above the falls. From that year to 1885, when the lands along the river were taken for a State park, a considerable amount of power was developed by a canal which took water out of the river near the head of the rapids and followed along the shore nearly parallel with the bank of the river. Mills were built between this canal and the river, and a part of the 50-foot fall between the head of the rapids and the brink of the American Falls was thus utilized. A paper mill was built on Bath Island at an early date.

In 1842 Augustus Porter, one of the principal mill owners at Niagara Falls, proposed a considerable extension of the then existing system of canals and races, and in January, 1847, in connection with Peter Emslie, he published a formal plan which became the subject of negotiations with Walter Bryant and Caleb S. Woodhull. An agreement was finally reached by which they were to construct a canal and receive a plot of land at the head of the canal, having a frontage of 425 feet on Niagara River, together with a right of way 100 feet wide for the canal along its entire length of 4,400 feet, and about 75 acres of land near the terminus, having a frontage on the river below the falls of nearly a mile. The canal constructed under this agreement passes through what is now the most thickly settled part of the city of Niagara Falls.

Ground was broken by Messrs. Bryant & Woodhull in 1853 and the work carried on for about sixteen months, when it was suspended for lack of funds. Nothing further was done until 1858, when Stephen Allen carried the work forward for a time; later, in 1861, Horace H. Day took up the matter and completed a canal 36 feet wide, 8 feet deep, and 4,400 feet long, by which the water of the upper river was brought to a basin near the brink of the high bluff of the lower river and at an elevation of 214 feet above the lower river. Upon the margin of this basin various mills have been constructed, to the wheels of which water is conducted from the canal and discharged through the bluff into the river below. The first mill built on this hydraulic canal was a small gristmill, erected by Charles B. Gaskill in 1870 on the site of the present large flouring mill of the Cataract Milling Company.

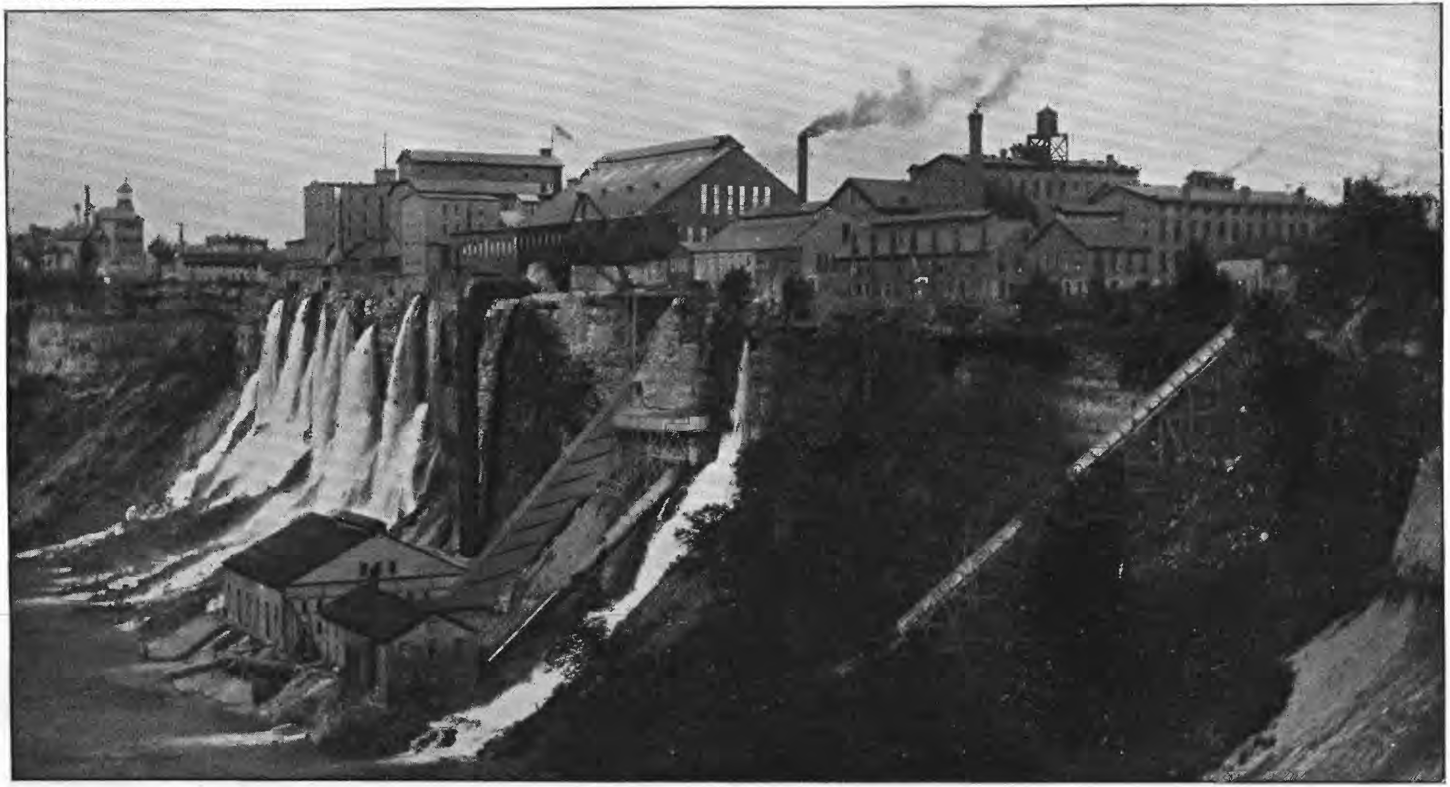
NIAGARA FALLS HYDRAULIC POWER AND MANUFACTURING COMPANY.

In 1877 the hydraulic canal and all its appurtenances were purchased by Jacob F. Schoellkopf and A. Chesbrough, of Buffalo, who organized the Niagara Falls Hydraulic Power and Manufacturing Company, of which Mr. Schoellkopf is still president. The following is a list of companies either now supplied or to be supplied with power by the Niagara Falls Hydraulic Power and Manufacturing Company.

Power furnished by Niagara Falls Hydraulic Power and Manufacturing Company.

WATER POWER.

Company.	Business.	Horse-power.
Central Milling Co	Flouring mill	1,000
N. Wood Paper Co	Paper and pulp	500
Schoellkopf & Mathews	Flouring mill	900
Pettebone Cataract Manufacturing Co	Paper and pulp	2,000
Cataract Milling Co	Flour	400
Niagara Falls Waterworks		200
Thomas E. McGarigle	Machine shop	25
Cliff Paper Co	Paper and pulp	2,500
Total		7,525
ELECTRIC POWER.		
Pittsburg Reduction Co	Aluminum	3,500
Niagara Falls and Lewiston R. R. Co		400
Cliff Paper Co	Paper and pulp	300
Lewiston and Youngstown R. R. Co		200
Buffalo and Niagara Falls Electric Light and Power Co.	Light and power	600
Niagara Falls Brewing Co		150
Rodwell Manufacturing Co	Silver plating, etc	75
Sundry small customers in Niagara Falls.		100
Francis Hook and Eye Co	Hooks and eyes	15
Kelly and McBean Aluminum Co	Aluminum	15
The National Electrolytic Co		1,000
Total		6,355
MECHANICAL POWER FURNISHED ON SHAFT.		
Oneida Co., Limited	Silver-plated ware and chains.	300
Carter-Crum Co	Check books	60
Total		360
Grand total		14,240



POWER HOUSE OF THE NIAGARA FALLS HYDRAULIC POWER AND MANUFACTURING COMPANY.

The contract made in 1852 between Augustus Porter, Walter Bryant, and Caleb J. Woodhull only conveyed lands to the edge of the high bank of Niagara River, but did not include the talus or slope between the edge of the high bank and the river, and only granted the right to excavate 100 feet down the face of the bank. In 1852, when this contract was made, the use of water power under higher heads than 100 feet was, so far as the United States was concerned, entirely unknown. Until recently the mills at Niagara Falls have not attempted to use more than 50 or 60 feet head; hence it resulted that although the capacity of the Niagara Falls Hydraulic Power and

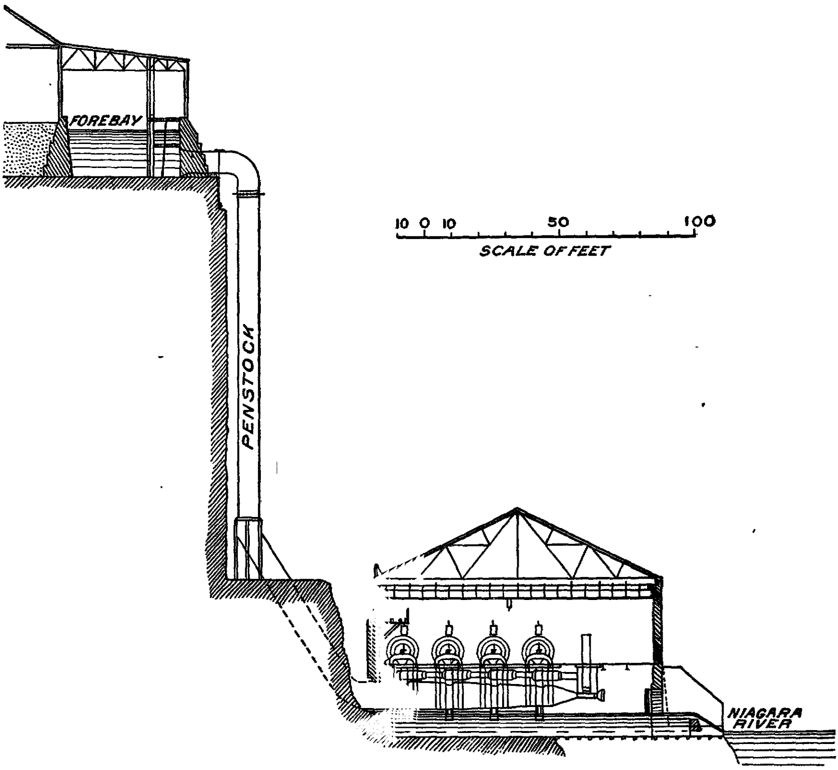


FIG. 2.—General plan of development of the Niagara Falls Hydraulic Power and Manufacturing Company.

Manufacturing Company's canal, as at first constructed, was sufficient, by development of the whole head, to produce about 15,000 horsepower, under the original agreements its capacity was exhausted when about 7,000 horsepower was produced.

In 1892 the Niagara Falls Hydraulic Power and Manufacturing Company began an enlargement and improvement of its canal. The plan adopted was to widen the original channel at one side to 70 feet, and make the new part 14 feet deep. This work is cut entirely through rock, below the water line. The enlargement of one side was completed in 1896. The canal as enlarged to date has a capacity of about 3,000 cubic feet per second, giving, under present conditions, a total of from 40,000 to 50,000 horsepower, the cross section being about 400 square feet.

This company has a grant from the State of the right to draw from Niagara River as much water as can be taken through a canal 100 feet wide and 14 feet deep. Work on further enlargement is now in progress, and it is expected, within a year or two, to have a total of about 675 feet area of water section.

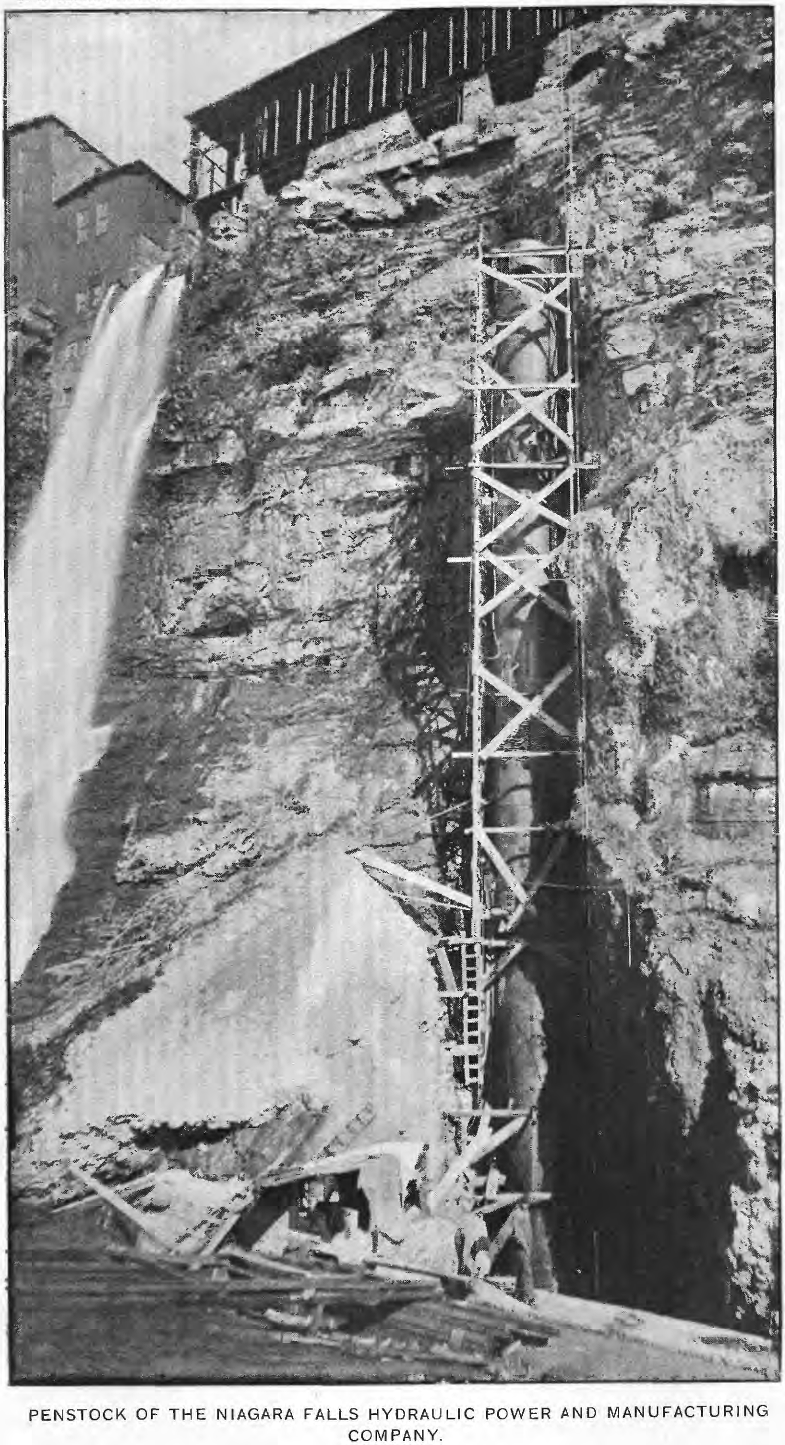
To July 1, 1897, about 100,000 cubic yards of material had been taken out at a cost of $250,000, the average cuttings in the original canal from the surface of the ground to the surface of the water being about 8 feet.

The development now in process by this company is very interesting. A bulkhead is located at the top of the high bank with a fore bay back of it connected with the main hydraulic canal by a short branch canal. From the fore bay a large penstock leads vertically down the cliff to a power house located directly on the shore of the lower river. In this power house horizontal turbine water wheels are placed, with dynamos directly connected, the power therefrom being transmitted either to the mills on the bluff above or to establishments at a distance. (See Pl. VII and fig. 2.) This company expects soon to transmit several thousand horsepower to Buffalo.[1] Without taking into account the cost of water in the canal, the cost of the development of power in the way in which it is now being developed by this company may be placed at $35 per horsepower.

NIAGARA FALLS POWER COMPANY.

The Niagara Falls Power Company has developed an extensive plant on quite different lines from that of the Niagara Falls Hydraulic Power and Manufacturing Company. In 1883 to 1885 Thomas Evershed, who was at that time division engineer of the western division of the New York State canals, was called on to survey Niagara Falls Park Reservation, as provided for by act of the legislature. This led Mr. Evershed to spend considerable time at Niagara Falls, during which he conceived the project of constructing a tunnel to begin at the level of the lower river and extend under the city of Niagara Falls for a distance of about 2½ miles. (See fig. 3.) This tunnel, as proposed, was to be generally parallel to the Niagara River, but at some little distance from it. At its head and at various points along the river from above Port Day it was proposed to construct branch canals

[1] For further details of the Niagara Falls Hydraulic Power and Manufacturing Company, see (1) Power development of Niagara Falls, other than that of the Niagara Power Company, by W. C. Johnson: Trans. Engineers' Society of Western New York, Vol. I, No. 6 (Feb. 3, 1896); (2) Niagara Falls Hydraulic Power and Manufacturing Company's new work, by Orrin E. Dunlap: Electrical Engineer, Vol. XX (Dec. 4, 1895); (3) Old hydraulic power plant at Niagara Falls transformed for electrical transmission, by Orrin E. Dunlap: Western Electrician, Vol. XIX (Dec. 5, 1896); (4) Pulp mill of the Cliff Paper Company of Niagara Falls, New York, by W. C. Johnson: Trans. Am. Soc. Civil Eng., Vol. XXXII (Aug., 1894).



PENSTOCK OF THE NIAGARA FALLS HYDRAULIC POWER AND MANUFACTURING COMPANY.

connecting with the river and through which water could be taken, to be discharged upon turbine wheels placed in vertical wheel pits and connected with the tunnel at various points.

The Niagara River Hydraulic Tunnel, Power and Sewer Company of Niagara Falls was incorporated in 1886 for the purpose of constructing and operating, in connection with Niagara River, a hydraulic tunnel or subterranean sewer for public use in the disposal of sewage and drainage and for furnishing hydraulic power for manufacturing purposes in the town of Niagara Falls. In consideration of the public service of sewerage and drainage, this company was authorized to acquire land by condemnation.

The general plan of development is described by Mr. Evershed in

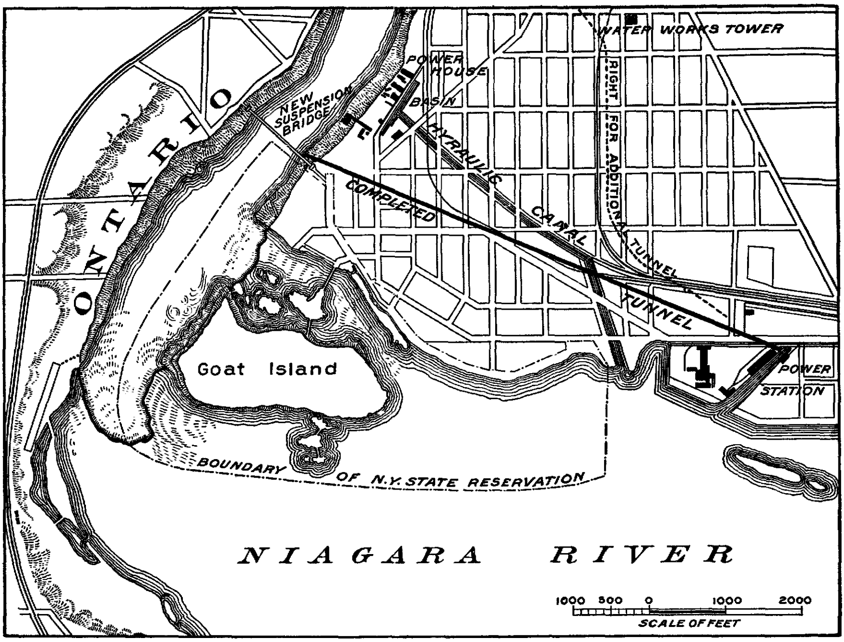


FIG. 3.—Map of Niagara Falls and vicinity, showing location of the great tunnel. (From Cassier's Magazine, Vol. VIII, p. 183.)

a report made July 1, 1896, in which he states that the main tunnel would begin at a point on the lower river immediately north of the State reservation, with its mouth as low as high water below the falls would permit. From this point to half a mile above Port Day it should have a rise of 1 foot in 100, or 52.8 feet per mile, and a section above Port Day equivalent to a circle 24 feet in diameter, the tunnel gradually diminishing in size in accordance with the number of mills emptying tail-water into it, until at the upper end it would have the same area of cross section as the connecting cross tunnels.[1]

The matter remained in abeyance until 1889, when the Niagara Falls

[1] See pamphlet, Water Power at Niagara Falls, prospectus of the Niagara River Hydraulic Tunnel, Power, and Sewer Company (1886).

Power Company was organized to carry out, in effect, Mr. Evershed's plan. The actual work of construction was undertaken by the Cataract Construction Company, composed of William B. Rankine, Francis Lynde Stetson, Pierpont Morgan, Hamilton McK. Twombly, Edward A. Wickes, Morris K. Jesup, Darius Ogden Mills, Charles F. Clarke, Edward D. Adams, Charles Lanier, A. J. Forbes-Leith, Walter Howe, John Crosby Brown, Frederick W. Whirtridge, William K. Vanderbilt, George S. Bowdoin, Joseph Larocque, John Jacob Astor, and Charles A. Sweet. This company has modified the original plans in some particulars, although the general scheme has been carried out.

The plan finally determined on comprised a surface canal 250 feet in width at its mouth on the river, 1¼ miles above the falls, extending inwardly 1,700 feet, with an average depth of 12 feet, and computed to furnish water sufficient for the development of about 120,000 horsepower. The masonry walls of this canal are pierced at intervals with inlets, guarded by gates. Some of these are used to deliver water to tenants who construct their own wheel pits and set their own wheels, while 10 of them are arranged on one side of the canal for the purpose of delivering water to the wheel pit of the Niagara Falls Power Company's power station, where dynamos, placed at the top of turbine vertical shafts, generate electricity for transmission. The wheel pit at the power station is 178 feet in depth and connected with the main tunnel by a short cross tunnel. The main tunnel as carried out has a maximum height of 21 feet and a width of 18.82 feet, making a net section of 386 square feet. The slope of this tunnel is 6 feet to the thousand.

The most careful consideration was given to the subject of the turbines to be used, as well as to the question of power transmission. In 1890 Edward D. Adams, who was then president of the company, established an International Niagara Commission, with power to offer $20,000 in prizes. This commission consisted of Sir William Thomson (now Lord Kelvin), Dr. Coleman Sellers, Lieut. Col. Theodore Turretini, Prof. E. Mascart, and Prof. W. C. Unwin. Inquiries concerning the best-known methods of development and transmission of power in England, France, Switzerland, and Italy were made, and competitive plans were received from twenty carefully selected engineers and manufacturers of power plants in England, Europe, and America. These plans were submitted to the commission, which awarded prizes to those considered worthy. The most important result was the selection of the designs of Faesch and Piccard, of Geneva, for turbines computed to yield 5,000 horsepower each. Three wheels have been built from these designs and are now in place and regularly operated.

Without going into details of the electrical work, it may be stated that the Niagara Falls Power Company adopted the two-phase alternating current system as best adapted to its work. In the dynamos employed the field magnet revolves instead of the armature. As

A. POWER HOUSE OF THE NIAGARA FALLS POWER COMPANY.

B. OUTLET OF TUNNEL OF THE NIAGARA FALLS POWER COMPANY.

advised by the company's electrical engineer, Prof. George Forbes, of London, three such dynamos, of 5,000 horsepower each, constructed by the Westinghouse Company, of Pittsburg, have been installed. During the summer of 1896 a transmission line was constructed from Niagara Falls to Buffalo, and since November of that year some of the street railways in Buffalo have been operated electrically by power from Niagara Falls.

According to a statement of William B. Rankine, secretary of the Cataract Construction Company, the power furnished or contracted for by the Niagara Falls Power Company July 1, 1897, was as follows:

Power furnished by the Niagara Falls Power Company.

HYDRAULIC POWER.

Company.	Business.	Horse-power.
Niagara Falls Paper Company	Paper	7,200
ELECTRIC POWER.		
Pittsburg Reduction Company	Aluminum	3,050
The Carborundum Company	Abrasives	1,000
Acetylene Light, Heat, and Power Company	Calcium carbide	1,075
Buffalo and Niagara Falls Electric Light and Power Company.	Local lighting	500
Walton Ferguson	Chlorate of potash	500
Niagara Electro-Chemical Company	Peroxide of sodium	400
Buffalo and Niagara Falls Electric Railway	Local railway	300
Niagara Falls and Suspension Bridge Railway Company.*a*	do	250
Buffalo Street Railway Company	22-mile transmission	1,000
Acetylene Light, Heat, and Power Company *b*	Calcium carbide	4,000
Mathieson Alkali Works *c*	Soda ash	4,000
Buffalo Street Railway Company		1,000
Buffalo General Electric Company *d*	Lighting	3,000
The Carborundum Company *e*	Abrasives	1,000
Niagara Falls Water Works Company		45
Power City Foundry and Machine Company		25
Albright and Wilson	Electro-chemicals	400
Total hydraulic power sold at Niagara Falls		7,200
Total electric power sold at Niagara Falls		14,545
Total electric power sold at Buffalo		5,000
Total		26,745

a All from October 1, 1896.
b From delivery, say, November 1, 1897.
c From June 1, 1897.
d From November 15, 1897.
e From June 1, 1897.

Recapitulation of the total power in use or furnished from Niagara Falls January 1, 1898, shows the following amounts:

	Horsepower.
Hydraulic power:	
Niagara Falls Power Company	7,200
Niagara Falls Hydraulic Power and Manufacturing Company	7,525
Electric power:	
Niagara Falls Power Company	19,545
Niagara Falls Hydraulic Power and Manufacturing Company	6,355
Mechanical power:	
Niagara Falls Hydraulic Power and Manufacturing Company	360
Total	40,985

The large demand for power from the Niagara Falls Power Company has necessitated the enlargement of the wheel pit and power house to more than three times their present capacity. The work upon this enlargement, sufficient to provide 35,000 additional horsepower, has been in progress since June, 1896, and is now approaching completion. With the completion of this extension the Niagara Falls Power Company will have available 50,000 horsepower; a portion of the increased power was ready for delivery January 1, 1898.

The 50,000 horsepower developed when the present extension is completed represents but one-half of the capacity of the present tunnel. This company has further secured the right of way for a second discharge tunnel, so that when the demand for power shall render it necessary the present plant may be duplicated, thus furnishing 200,000 horsepower in all. In addition to this large development on the American side, the Canadian Niagara Power Company, an allied corporation, now holds from the Canadian government an exclusive franchise granting to it the right to develop on the Canadian side at least 250,000 horsepower. The total possible power proposed to be developed in the future at Niagara Falls is about as follows:[1]

Power proposed to be developed at Niagara Falls.

	Horsepower.
Niagara Falls Power Company's present tunnel	100,000
Niagara Falls Power Company's second tunnel	100,000
Niagara Falls Hydraulic Power and Manufacturing Company's canal	150,000
Canadian Niagara Power Company's tunnels	250,000
Total	600,000

The developments now in progress at Niagara Falls are being carried out on very broad lines and probably furnish the best examples of modern hydraulic work. They certainly lead so far as the

[1] For an interesting discussion as to the effect of diverting large quantities of water from Niagara River for power purposes, see report of Clemens Herschel, made December 12, 1895, on the Diversion of Water from the Niagara River for Power Purposes by the Niagara Falls Hydraulic Power and Manufacturing Company and by the Niagara Falls Power Company, and the Unimportant Effect of such Diversion upon the River. Mr. Herschel bases his discussion on the data of the Lake Survey of an ordinary and usual flow of 265,000 cubic feet per second. Reasoning from this premise he concludes that even when 300,000 or 400,000 horsepower are in use the effect upon the depth of the river will be insignificant.

United States is concerned. A complete account of both works, giving details of all the engineering features, would make a large-sized monograph. From this point of view it is only possible to cite some of the sources of information.[1]

POWER PLANT AT MASSENA, ON ST. LAWRENCE RIVER.

Among the large power developments now under construction in the State of New York is that at Massena, on St. Lawrence and Grass rivers. According to statements made by John Bogart, consulting engineer, the power plant now under construction at Massena includes the excavation of a canal leading from St. Lawrence River to Grass River, a distance of 3 miles, the building of a power house, the installation of fifteen 5,000-horsepower electric generators, and the necessary equipment of turbine water wheels. The furnishing of the electric apparatus has been awarded to the Westinghouse Electrical and Manufacturing Company, and is said to be the largest contract for electric apparatus ever placed.

The plan of development adopted at Massena is to divert a portion of the water of St. Lawrence River from its natural channel by means of a canal, carrying it 3 miles across to Grass River, where, after operating turbines, it will pass by way of Grass River to the St. Lawrence at a point lower downstream. Just below where the canal takes water from St. Lawrence River, Long Sault Rapids are located, which have a fall of about 50 feet. Grass River runs nearly parallel to the St. Lawrence for several miles, flowing into the St. Lawrence a short distance below the foot of Long Sault Rapids. To the south of St. Lawrence River, and between it and the valley of Grass River, there is a comparatively level plateau.

The average width of Grass River from its mouth to above where the power canal will intersect it is from 250 to 300 feet, and its water surface, for this portion, is substantially on a level with the St. Lawrence below the rapids; hence the surface of Grass River at the point where the power canal strikes the stream is from 45 to 50 feet below the surface of the St. Lawrence at the head of the canal. The power station will be located on the north bank of Grass River, the tail-water dropping into that stream, which thus becomes, in effect, a tailrace for this power development. Making some allowance for increased depth of water in Grass River between the power station and its mouth, when receiving the tail water, and also some allowance

[1] The main facts in regard to the plant of Niagara Falls Power Company as herein embodied have been furnished by L. H. Groat, secretary of the company. For more extended information the reader is referred to (1) Cassier's Magazine, Vol. VIII (July, 1895), where may be found an account of nearly every phase of the Niagara Falls Power Company's development; (2) The Electrical World, Vol. XXX (Oct. 23, 1897), which may be consulted for a description of the extension of the wheel pit now in process; (3) Niagara Falls publication of the Niagara Falls Chamber of Commerce, issued in 1897; (4) the various numbers for 1897 of Greater Buffalo, a monthly publication devoted to promoting the prosperity of Buffalo and Niagara Falls. Engineering News and other technical jonrnals may also be consulted.

for inclination of the water surface of the head canal, it is thought that an absolutely permanent power of about 40 feet will be obtained.

The work of constructing the head canal and preliminary work on the foundations of the power house are now under way. It is expected that the work will be completed in 1899. The canal will be 250 feet wide and 25 feet deep, this capacity being assumed as sufficient to furnish 150,000 horsepower. The work is being carried out by the St. Lawrence Power Company, which was organized under the laws of the State of New York, with a capital stock of $6,000,000. According to statements made, a large amount of power has been taken by an English syndicate, which intends to use it chiefly for electro-chemical manufacturing.

INLAND WATERWAYS.

TRADE AND COMMERCE OF HUDSON RIVER.

The importance of Hudson River as a great waterway of commerce is shown by Mr. Charles G. Weir in a report made in 1890. Aside from its own local trade the river absorbs all the traffic of the Erie, Champlain, Delaware, and Hudson canals, besides the great coal trade of the Pennsylvania Coal Company at Newburg and the Erie coal trade at Piedmont. The average season of navigation of the river is two hundred and forty days. The two principal industries on Hudson River, which add materially to the total tonnage, are ice and brick. The capacity of the ice houses on and near the river exceeds 4,000,000 tons, and the amount annually harvested is about 3,500,000 tons. The bricks manufactured on the river exceed 850,000,000.

The following statistics include the tonnage received at all points above Spuyten Duyvil Creek, and of the local shipment between points on the river. That shipped is credited only to the points from which it was shipped, no entry being made to the total tonnage of the amount received at local points from other local points. The total tonnage also includes all through freights shipped from points up the river that passed the mouth of Spuyten Duyvil Creek going south.

Tonnage and value of commerce on Hudson River above Spuyten Duyvil Creek.

Total tonnage of all shipping points on Hudson River during 1889, not including the tonnage coming through State canals (tons)	15,033,309
Value of same	$378,196,094
Total tonnage coming to and leaving tide water through State canals, 1889 (tons)	3,592,437
Value of same	$108,000,000
Increase of same over tonnage, 1888 (tons)	326,466
Grand total tonnage of Hudson River, including tonnage through State canals (tons)	18,582,596
Value of same	$485,735,094
Number of transportation companies for passengers or freight, not including steamboats or pleasure boats	30
Total number of passengers carried, 1889	5,000,000

In regard to the foregoing statement of the capacity of ice houses on and near the river, as made by Mr. Weir, it may be remarked that Charles C. Brown, in a report on Hudson River, which appears in the Eleventh Annual Report of the State Board of Health, gives a list of ice houses on Hudson River, with their capacity in 1889. According to Mr. Brown, the total capacity in that year was 2,908,000 tons, while the crop harvested frequently exceeds this quantity by 500,000 tons, which is stacked up outside and disposed of before the warm season begins. Mr. Weir's statistics, as stated, include the capacity of ice houses on and near Hudson River, while Mr. Brown's include only those actually on the river, which probably explains the apparent discrepancy in the statistics.

STATE CANALS.

EARLY HISTORY.

The idea of a water communication between Hudson River and the West via the valley of the Mohawk had been a favored one with the statesmen of New York for many years previous to the beginning of the present century; the early projects, however, were altogether with reference to improvement of the natural water channels and did not include the construction of artificial channels further than such channels might be necessary as connecting links. Thus Sir Henry Moore, governor of the colony of New York, proposed, in December, 1768, an improvement of the navigation of the Mohawk River at Little Falls by a sluice on the plan then used on the Languedoc Canal in France.

In 1788 Elkhannah Watson proposed to establish a water communication from Hudson River and Lake Ontario by way of Oneida Lake, Oneida River, and Oswego River, his plan being to connect Wood Creek with Mohawk River by a canal and to improve the Mohawk with locks.

In January, 1791, Governor George Clinton, in an address to the legislature, urged the necessity of improving the natural water channels in order to facilitate communication with the frontier settlements. Following this address, in February of the same year, a joint committee was appointed to inquire what obstructions in the Hudson and Mohawk rivers it would be proper to remove. As the result of this inquiry, an act was passed March 24, 1791, authorizing the commissioners of the land office to explore and survey the ground from Mohawk River at Fort Stanwix (now Rome) to Wood Creek with reference to constructing an artificial channel, and also to survey Mohawk and Hudson rivers for improvement by locks and to estimate the cost of the same. A sum not exceeding $500 was appropriated to pay the expense of such survey.

At that time the channel of commerce was by the Mohawk from Albany to Fort Stanwix in boats of about 5 tons burden. Going west these boats carried from 1½ to 2 tons and on the easterly trip 5 tons. From Fort Stanwix there was a portage of 2 miles across the flats to Wood Creek, whence the course lay into Oneida Lake and River, and from thence into Seneca and Oswego rivers to Lake Ontario; or, from points farther west, up Seneca River to Lakes Cayuga and Seneca. At that time it cost from $75 to $100 per ton for transportation from Seneca Lake to Albany. The time occupied in going from Albany to Seneca Lake was twenty-one days, and in returning eight days.

The commissioners appointed under the act of March, 1791, were Elkhannah Watson, Gen. Phillip Schuyler, and Goldsborrow Bayner. On the 3d of January, 1792, the commissioners reported the cost of improving the route from Albany to Seneca Lake by locks and canals at $200,000, whereupon the legislature passed an act March 30, 1792, incorporating the Western Inland Lock Navigation Company, for the purpose of opening navigation by locks from Hudson River to Lakes Ontario and Seneca, and the Northern Inland Lock Navigation Company, charged with performing a like service from Hudson River to Lake Champlain. The capital stock of each company consisted of 1,000 shares of $25 each, but the companies were afterwards allowed a capital stock of $300,000 and an increase of the same from time to time. George Washington, the original promoter of canals in the United States, was the first president of the Western Inland Lock Navigation Company.

In March, 1795, an act was passed directing the State treasurer to subscribe 200 shares to these companies, of $50 each. State aid was again granted by an act passed in April, 1796, by which the Western Inland Lock Navigation Company was loaned $37,500, and a mortgage taken by the State on the company's property at Little Falls. In that year a route was opened from Schenectady to Seneca Falls for boats carrying 16 tons. The locks at Little Falls were first built of wood, then of brick, and finally of stone; the remains of the latter are said still to exist. Dividends were paid for a number of years on the stock of the company making these improvements. The tariff levied for a barrel of flour carried 100 miles was 52 cents, and for a ton of goods, $5.75.

Finally New York entered upon its era of inland-water improvements under the auspices of the State itself. On April 15, 1817,[1] an act was passed entitled "An act respecting navigable communication between the great eastern and northern lakes and the Atlantic Ocean," in which it was provided that whenever in the opinion of the canal commissioners it should be for the interests of this State that all the interest and title in law and equity of the Western Inland Lock Navigation Company shall be vested in the people of this State, it should

[1] The full authority for the construction of the Erie and Champlain canals may be found in two acts, the first being chapter 237 of the laws of 1816, passed April 17, 1816; the second being chapter 262 of the laws of 1817, passed April 15, 1817. There is more or less confusion of these two dates in early canal literature.

be lawful for the canal commissioners to pass a resolution to that effect. The act then provides a procedure for taking the property of this company after the passage of such a resolution by the canal commissioners. Following this act the rights of the company were soon transferred to the State, and the property operated for two or three years thereafter under State auspices. In 1821 the State collected the sum of $450.56 for tolls charged from Rome to the lower lock at Little Falls on account of transportation over the route formerly controlled by the Western Inland Lock Navigation Company.

Chapter 144 of the laws of 1813 incorporated the Seneca Lock Navigation Company for the purpose of constructing a canal from Cayuga Lake to Seneca Lake. The rights of this company were purchased by the State, pursuant to chapter 271 of the laws of 1825. The two companies, the Western Inland Lock Navigation Company and the Seneca Lock Navigation Company, may be considered the forerunners of Erie Canal.

About $100,000 was expended by the Northern Inland Lock Navigation Company on locks around the falls at Cohoes and for their improvement, all of which proved a total loss, the rights of the company being finally transferred to the State before navigation from Hudson River to Lake Champlain was actually opened.

The amount expended by the Western Inland Lock Navigation Company up to December, 1804, was $367,743, which was increased to $480,000 in 1813, and to a total of $560,000 before the works were finally transferred to the State. The mistake of first constructing wooden locks proved a severe loss to the company, as all the original locks at Little Falls, German Flats, and Rome rotted away in about six years. The facilities afforded by these companies were undoubtedly inadequate to the demands of the rapidly growing western section, and accordingly an active agitation finally began for some more extended means of communication.

The early work was, as we have seen, entirely in the direction of the improvement of natural channels, the extent of artificial channels for the whole route from Hudson River to Seneca Lake being only 15 miles. About 1803, however, the project for an artificial canal connecting Lake Erie with tide water in the Hudson was broached by Gouverneur Morris. In 1807 Jesse Hawley wrote a series of articles on the subject; and in 1808 the legislature directed the surveyor-general, Simeon De Witt, to make a survey of such a route. This survey was made by James Geddes, who reported on January 20, 1809. In 1810 the legislature appointed commissioners to prosecute further examinations. This commission made its first report in March, 1811. After discussing the route as proposed, from Hudson River to Lake Ontario, it recommended the inland route to Lake Erie with a direct descent from Lake Erie to Hudson River. Following this report a bill was passed by the legislature reappointing the commissioners of the previous year, with the addition of Robert R. Livingston and Robert Fulton, and extending the powers of the commissioners and adding to the appropriation for its work. The war of 1812 came on, however, and the canal project was temporarily dropped until 1816, when De Witt Clinton presented a memorial to the legislature from the city of New York urging action toward the construction of the canal. Finally the act of April 15, 1817, was passed creating a permanent board of canal commissioners,[1] which entered at once upon its duties, and providing for the construction of artificial navigation from Lake Erie to tide water on Hudson River, and also from Lake Champlain to tide water on the Hudson. The dimensions of the proposed canals were fixed by the commissioners as follows: For Erie Canal a bottom width of 28 feet, surface width 40 feet, and depth 4 feet, with locks 90 feet long and 15 feet wide; for Champlain Canal a bottom width of 20 feet, surface width 30 feet, and depth 3 feet, with locks 75 feet long and 10 feet wide.

Ground was broken for Erie Canal at Rome, July 4, 1817, and the section from Utica to Seneca River completed October 22, 1819, a boat passing from Rome to Utica on that day. Champlain Canal was opened in part for navigation November 24, 1819. The route for Erie Canal from Seneca River west was also explored in 1819, and the final location, from Seneca River to Rochester, made in 1821. The principal engineers were James Geddes, Benjamin Wright, and Canvass White.

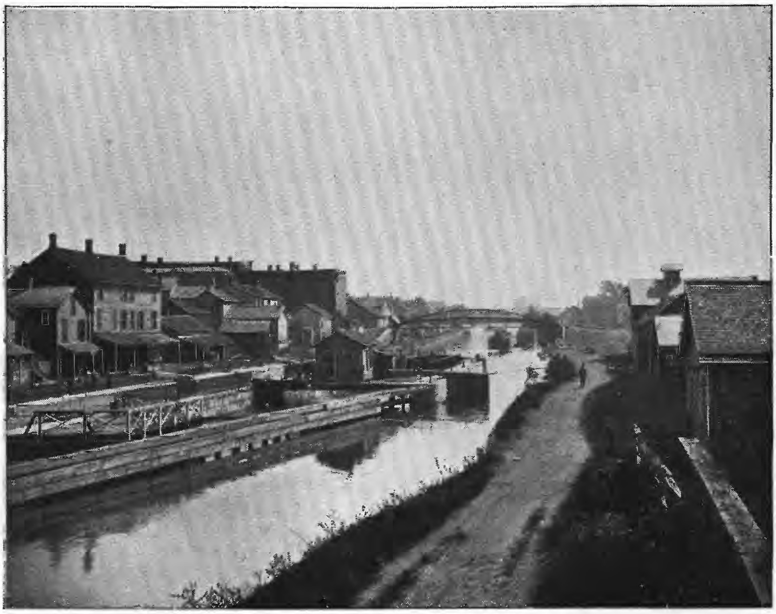
The annual report of the canal commissioners, dated January 31, 1818, gives details of the system adopted for the construction of the canal. They state that they had decided to complete the middle section first, 58 miles of which were put under contract during the year 1817, this portion being wholly on the summit level. The whole labor performed in 1817 was equal to the completion of 15 miles. In indication of the easy character of the work, the commissioners state that three Irishmen finished 3 rods of canal in 4 feet cutting in five and one-half days, and that on the 58 miles under contract only half a mile required puddling.

The engineer's original estimate of the cost of the middle section, completed in 1819, was $1,021,851. The actual cost was $1,125,983. This increase, as stated by the commissioners, was due to change of prism and structures.

While the State canals were in progress the Seneca Lock Navigation Company, authorized by chapter 144 of the Laws of 1813, had been engaged in constructing a canal between Seneca and Cayuga lakes, including a series of locks at Seneca Falls. On June 14, 1818, a loaded boat from Schenectady, 16 tons burden, passed the newly-constructed locks at Seneca Falls. Along Mohawk River the passage

[1] The permanent board of canal commissioners of 1817 included the following men: De Witt Clinton, president; Stephen Van Rensselaer, Samuel Young, Joseph Ellicott, and Myron Holley, their appointment having been first authorized by the act of April 17, 1816.

A. ERIE CANAL AT BUFFALO, NEW YORK



B. BLACK ROCK GUARD LOCK ON ERIE CANAL of boats of this size was effected through the locks of the Western Inland Lock Navigation Company, Erie Canal not being open for navigation at that date. The locks at Seneca Falls cost $60,000. The toll charged during 1818 was equivalent to 9 cents per ton per mile.

Champlain Canal was, as stated, opened for navigation November 24, 1819, from the Hudson at Fort Edward to Lake Champlain. The estimated cost of this section was $250,000, but on account of changing its dimensions to the same size as Erie Canal the revised estimate amounted to $333,000. The canal was finally completed from Lake Champlain to Albany on September 10, 1823.

Work on Erie Canal proceeded during the years from 1820 to 1825, in the former year 94 miles being in operation and in the latter 363. It was finally completed from Albany to Black Rock on October 26, 1825, on which day the first boat ascended the Lockport locks and passed through the mountain ridge into Lake Erie. Uninterrupted navigation was thus obtained from that lake to the Atlantic Ocean for boats of an average of about 40 tons burden. The event was made a gala day the whole length of the canal.

The construction of Erie Canal was due to the unbounded perseverance and genius of one man—Governor De Witt Clinton—who, when one studies the early history of Erie Canal, stands forth as the colossal figure of the enterprise.

The total expenditure on Erie and Champlain canals to January 1, 1826, was $9,474,373.14, from which should be deducted for pay of engineers and commissioners, the acquisition of water rights, land damages, the construction of feeders, repairs, Black Rock Harbor, lowering Onondaga outlet, Salina and Onondaga side cut, Waterford and Troy side cuts, Troy dam, and Glens Falls feeder, the sum of $1,621,274. Hence the actual cost of construction of the canal proper was $7,853,099, which, on the aggregate length of 433 miles, equals $18,136 per mile, or, taking into account the various extensions enumerated and the engineering as necessary items of expenditure, the original cost per mile of the Erie and Champlain canals may be placed at $21,881 per mile.

Between 1825 and 1833 work was begun on a number of lateral canals—as, for instance, Oswego Canal, begun in 1826 and completed in 1828; Cayuga and Seneca Canal, begun in 1827 and completed in 1829; Chemung Canal, begun in 1831 and completed in 1832, and Crooked Lake Canal, begun in 1831 and completed in 1833. The total cost of all the canals, including interest on loans up to March 23, 1833, was $11,460,066.77.

Chenango Canal was begun in 1833. The total amount expended on all the canals, including original construction, extensions, maintenance, repairs, and interest on loans, to the end of 1834 was $13,798,438, and the total amount of tolls received from 1820 to 1834, inclusive, was $10,000,730.97—that is to say, at the end of ten years from the original completion of Erie Canal the amount returned to the State was nearly 78 per cent of the total cost to that date. This fact is of the greatest interest because it indicates that from the very beginning the New York State canal system was operated as a purely business enterprise. It is clear, then, that in reality the State of New York, in constructing its internal navigation system, went into the transportation business; by that statement it is meant that the State managed the affairs of the canals precisely as a private company would have managed them—that is, the State built its canal system and levied as heavy tolls as the articles transported would stand.

By way of illustrating how thoroughly the State was in the transportation business and on exactly the same basis as transportation companies, it may be cited that in 1830 the legislature sent a communication to the commissioners of the canal fund asking if it were not possible to increase the rate of toll on many of the articles transported, and stating that it seemed necessary, in order to meet all the interests involved, that the canals yield somewhat greater revenue. The commissioners replied to this communication at length, giving in detail the amount of toll levied on different articles transported, and finally concluded with the statement that it would be impossible to increase the tolls materially, because the articles transported were at that time taxed all they would stand. If the rate of toll were made materially greater, many articles would not be transported on the canals, but would go by other channels, as by St. Lawrence River and by the Great Lakes. The State would thus lose the benefit derived from carrying them.

About 1833 to 1835 railroads began to attract attention as means of transportation, and in 1835 John B. Jervis, Holmes Hutchinson, and Frederick C. Mills, who were the principal canal engineers of that day, were instructed to report on the relative cost of transportation on canals and railroads. In an introduction to their report by William C. Bouck and Michael Hoffman, canal commissioners, it is stated that it will not be difficult to show that the expense of transportation on railroads is materially greater than on canals. But in addition to this there were other important considerations in favor of canals:

(1) A canal may be compared to a common highway on which every man can be the carrier of his own property, therefore creating the most active competition, and thus reducing the expense of transportation to the lowest rates. The farmer, merchant, and manufacturer can avail themselves of the advantages of carrying their own product to market in a manner best comporting with the interest of each individual.

(2) Much of the property carried on the canals is carried by transportation companies, although the largest portion is carried by individuals and small associations. The individual who becomes the

carrier of his own product has the advantage of paying nearly one-half of all the expense of transportation in the regular course of his business, and the cash disbursements do not often much exceed the payment of the tolls. To the farmer the profits on return freight, in many instances, give a full indemnity for the expense of taking his cargo to market. On railroads, on the other hand, the proprietors must necessarily be the carriers.

A fixed popular belief in the two principles laid down by Messrs. Bouck and Hoffman in their introduction to the transportation report of 1835 has been the cause of a great deal of mistaken policy in the State of New York. For instance, nearly every year since the beginning of the railway era the newspapers of the State have teemed with the statement that the State must necessarily maintain the canal system in order to check the exorbitant tariff demands of competing railways. As we have seen, in 1830, just before the beginning of the railway era, the State was taxing every article transported upon the canals all that it would stand, and the system of excessive State tariffs was continued until a few years later, when the competition of the railways forced a reduction in the tariff for transportation on the canal.

GROWTH AND DECLINE OF CANAL TRANSPORTATION.

A number of reports bearing on transportation questions were submitted in 1835, and finally the fixed policy was adopted of enlarging Erie Canal, the act authorizing what is known as the Erie Canal enlargement being passed in that year. The law authorizing the enlargement directed the construction of double locks and a prism with a width at water surface of 70 feet, and a depth of 7 feet, the locks to be 110 feet long and 18 feet wide. It was estimated that an enlargement to this extent would save 50 per cent in cost of transportation, exclusive of tolls. The enlargement to this standard width and depth was begun in 1836 and continued to 1842, when the legislature directed the suspension of expenditures. In 1847 the work of enlargement was resumed, and substantially completed in 1862. Since that time to the work now in progress under the authority of chapter 79 of the laws of 1895 there has been no change in the standard of width at water line of 70 feet and depth of 7 feet. As an interesting fact it may be pointed out that while the enlargement authorized in 1835 led to vast increase in the transportation business on the State canals the cost of transportation gradually decreased, one chief cause of such decrease being the competition of railways, until in 1883 the competition from this source became too sharp to maintain longer transportation on the canals if any toll at all were charged. The canals were then made free by legislative enactment.

The popular notion, formerly prevalent in New York, that it has been necessary to maintain the State canals in order to regulate the railways, is seen to be far from true. The railways have regulated the canals quite as much or more than the canals have regulated the railways. Indeed, the railways must be considered as having the better of it, because the State has been obliged absolutely to do away with all tolls on the canals in order to insure their obtaining business at all.

In illustration of the value of the water resources afforded by the Great Lakes in conjunction with the New York State internal navigation system, the following statement of receipts of flour, wheat, corn, oats, barley, and rye at Buffalo for certain years, from 1836 to 1896, inclusive, is given.

Receipts of flour, wheat, corn, oats, barley, and rye at Buffalo from 1836 to 1896.

Year.	Flour.	Wheat.	Corn.	Oats.	Barley.	Rye.
	Barrels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
1836	139,178	304,990	204,355	28,640	4,876	1,500
1840	597,142	1,004,561	71,337	----------	----------	----------
1845	746,750	1,770,740	54,200	23,300	----------	----------
1850	1,103,039	3,681,347	2,593,378	357,580	3,627	----------
1855	937,761	8,022,126	9,711,430	2,693,222	62,304	299,591
1860	1,122,335	18,502,615	386,217	1,209,594	262,158	80,822
1865	1,788,393	13,437,888	19,840,901	8,494,799	820,563	877,676
1870	1,470,391	20,556,722	9,410,128	6,846,983	1,821,154	626,154
1875	1,810,402	32,987,656	22,593,891	8,494,124	916,889	222,126
1880	1,317,911	40,510,229	62,214,417	649,351	335,925	743,451
1885	2,993,280	27,130,400	21,028,230	767,580	577,230	309,370
1890	6,245,580	14,868,630	44,136,660	13,860,780	5,165,700	1,281,030
1895	8,971,740	46,848,510	38,244,960	21,943,680	10,253,440	787,340
1896	10,384,184	54,411,207	47,811,010	40,107,499	16,697,744	4,404,354

A comparison of the statistics of railroad and canal traffic shows at once the vast preponderance of freight carried by the several railways centering at New York in comparison with that carried by Erie Canal. In spite of the fact that the canal was made free in 1883, figures indicate that since that time there has been a continual decrease in the amount of freight carried on the canals. Probably no feature of this change is more significant than that of the internal movement in New York State. In 1889 the total movement within the State was 1,438,759 tons, while in 1896 it was only 565,482 tons. These statistics show at once the decreasing estimation in which Erie Canal as a means of transportation is held by the great body of shippers in the State of New York. One of the results of this decrease is graphically

EFFECT OF DECREASE OF BUSINESS ON ERIE CANAL.

depicted in Pl. X, showing the fleet of boats tied up and awaiting business.

By way of illustrating the growth and decline of the business of the New York State canals from about 1835–36 to the present time the following statement of total tonnage of all freight on the canals, ascending and descending, and the value of the same for certain years from 1837 to 1896, inclusive, is presented:

Tonnage of freight on New York State canals and value of same, 1837 to 1896.

Year.	Tons.	Value.
1837	1,171,296	$55,809,288
1840	1,416,046	66,303,892
1845	1,977,565	100,629,859
1850	3,076,617	156,397,929
1855	4,022,617	204,390,147
1860	4,650,214	170,849,198
1865	4,729,654	256,237,104
1870	6,173,769	231,836,176
1875	4,859,958	145,008,575
1880	6,457,656	247,844,790
1885	4,731,784	119,536,189
1890	5,246,102	145,761,086
1895	3,500,314	97,453,021
1896	3,714,894	100,039,578

Without analyzing the figures in detail, it is sufficient to point out that if it is true, as popularly supposed, that Erie Canal ought to be maintained as a medium of competition with the railways, the figures derived from the annual statements of the chief competitor of Erie Canal must be taken as conclusive that the competition has, on the whole, been a failure. The railway, developed as a private enterprise, has not only been able to carry freight as cheaply as the canal, but has been able to charge for the same and do the work at a profit. In the year ending June 30, 1897, the New York Central and Hudson River Railway Company paid a dividend on its stock of $4,000,000, besides carrying $51,866.80 to the surplus account, whereas the canal, although all tolls were removed in 1883, has still been unable to compete. Among the chief reasons for this result we may mention lack of organization of the canal system. The perpetuation of the idea that one advantage of the canals was that they were common highways on which each man could carry his own products to market has tended largely to produce this unsatisfactory result. Thus far there has never been any systematic organization for obtaining business for the canal. The boats are owned by small proprietors, each operating from one to three or four boats. When cargoes in hand are discharged at either terminus, each owner solicits another cargo. The results are delays, half cargoes, and consequent loss. During the last few years it has been only by the most rigid economy that Erie Canal boatmen could live. On the other hand, the business of soliciting freight for the railways is compactly organized and every possible advantage taken of the situation.

However unsatisfactory it may seem to the individual boatman, the future of effective transportation on Erie Canal depends, in the opinion of the author, on the organization of large transportation companies which conduct the business of carrying freight by canal on the same business basis as adopted by railways. As to the equity of the State furnishing and maintaining a waterway on which transportation may be conducted by such corporations at a profit the author expresses no opinion further than to point out that the official discussion of such a proposition by the State engineer and surveyor in his annual report for the year ending September 30, 1896, may be taken to indicate that the day of Erie Canal as a State waterway has passed.

COST AND REVENUES OF THE NEW YORK STATE CANAL SYSTEM.

The accompanying table exhibits the total cost of construction, maintenance and operation, and the total revenues from all sources of the several canals of New York from their original inception to September 30, 1892.

Cost of construction, maintenance and operation, and revenues of New York canal system.

Canals.	Cost of construction.	Cost of maintenance and operation.	Total cost.	Revenue from all sources.	Loss.	Gain.
Erie and Champlain	$57,688,676	$41,582,759	$99,271,435	$128,191,068		$28,919,633
Oswego	4,643,921	3,736,676	8,380,597	3,715,567	$4,665,030	
Cayuga and Seneca	1,886,662	1,157,754	3,044,416	1,055,016	1,989,400	
Black River	4,077,882	2,082,251	6,160,133	305,663	5,854,470	
Oneida River improvement	233,962	41,236	275,198	214,428	60,770	
Oneida Lake	513,439	144,060	657,499	65,180	592,319	
Baldwinsville (so called)	31,000	18,039	49,039	1,261	47,778	
Seneca River towing path	1,602	20	1,622	7,782		6,160
Cayuga Inlet	2,020	948	2,968	7,534		4,566
Crooked Lake (abandoned)	395,092	424,658	819,750	45,490	774,260	
Chenango (abandoned)	4,807,952	2,105,217	6,913,169	744,027	6,169,142	
Chemung (abandoned)	1,512,041	2,022,259	3,534,300	525,565	3,008,735	
Genesee Valley (abandoned)	6,741,839	2,814,809	9,556,648	860,165	8,696,483	
Total	82,536,088	56,130,686	138,666,774	135,738,746	31,858,387	28,930,359

The total cost of Crooked Lake, Chenango, Chemung, and Genesee Valley canals, which were abandoned under the provisions of the law of 1877, was $20,823,867, and the total revenue from all sources $2,175,247. The total loss on the abandoned canals was, therefore, $18,648,620. The following is the complete financial exhibit of all canals from their inception to September 30, 1892: Total loss on abandoned canals, $18,648,620; net gain on canals now in operation, $15,720,592; loss on the whole system, $2,928,028.

IMPROVEMENT OF ERIE CANAL.

The canal improvement now in progress was formulated by State Engineer and Surveyor Horatio Seymour, jr., about 1878 or 1879. In his annual report for the fiscal year ending September 30, 1878, Mr. Seymour discusses extensively transportation questions as related to Erie Canal, pointing out that transportation can be cheapened in two ways—by increasing the tonnage of boats or by increasing their speed. As to increasing the tonnage of boats, he states that two methods may be used—the locks may be lengthened or the depth of water may be increased. He refers to experiments made by Elnathan Sweet by which it was shown that the best form of waterway should have a cross section 5.39 times the immerged section of the boat, and a surface width 4.5 times the width of the boat. The width of the canal, Mr. Seymour states, is substantially what it should be, but it lacks the necessary depth in order to conform to the law of relation of cross section of water to immerged section of boat, as determined by Mr. Sweet. Reports are submitted showing that an additional depth of 1 foot could be obtained for about $1,100,000.

The matter of making the improvement, however, remained in abeyance until the passage of an act in 1895, which provided for submitting to the people at the State election in November of that year the question as to whether an improvement by deepening 2 feet should be undertaken, at an expense of $9,000,000. Section 3 of chapter 79 of the laws of 1895 reads as follows:

Within three months after issuing of the said bonds the superintendent of public works is hereby directed to proceed to enlarge and improve the Erie Canal, the Champlain Canal, and the Oswego Canal; the said improvement to the Erie and Oswego canals shall consist of deepening the same to a depth of not less than 9 feet of water, except over and across aqueducts, miter sills, culverts, and other permanent structures, where the depth of water shall be at least 8 feet, but the deepening may be performed by raising the banks wherever the same may be practicable; also the lengthening or improving of the locks which now remain to be lengthened, and providing the necessary machinery for drawing boats into the improved locks, and for building vertical stone walls, where, in the opinion of the State engineer and surveyor and superintendent of public works, it may be necessary. The improvement upon the Champlain Canal shall consist in deepening the said canal to 7 feet of water, and the building of such vertical stone walls as, in the opinion of the State engineer and surveyor and superintendent of public works, may be necessary.

The necessary preliminary work was so far completed that bids for constructing the improvement were called for in October, 1896, and shortly thereafter contracts for work amounting to about $4,000,000 were awarded. The canal was closed December 1, 1896, and soon after work was begun and continued until May 5, 1897, when navigation was opened for the season of 1897, and all contractors not working with dredges discontinued operations until the winter of 1897–98. The act authorizing the present improvement provided, as we have seen, that the deepening of the canal prism might be accomplished either by excavation or by raising the side walls. As a matter of fact, sometimes one method and sometimes the other has been followed, depending upon the conditions of each level. Usually, however, a part of the increased depth has been obtained by raising the side walls, with the balance secured by excavation.

As is indicated in the extract from the act authorizing the present improvement, the work includes the lengthening of such locks as have not been previously lengthened. The original locks of the enlargement of 1836 to 1862 were 110 feet long by 18 feet wide. In 1885 work was begun lengthening these locks to 220 feet, or about 210 feet in the clear, thus permitting two boats to pass through at one lockage. Up to the present time 42 of the 72 original locks have been lengthened. The 30 locks yet remaining to be dealt with are mostly bunched in groups or flights, as, for instance, at Cohoes, where 16 locks effect a change of level of 140 feet, and at Lockport, where 5 locks effect a change of 58 feet. In order to lengthen locks built in flights it would be necessary to entirely reconstruct them, and as the restricted space, especially at Lockport, would render this a very difficult thing to do in one winter season, it has therefore been proposed to construct at Cohoes and Lockport, and possibly at Newark, vertical lift locks to take the place of the ordinary locks now in use at these places. The State engineer and surveyor has completed the plans for the proposed lift lock at Lockport, which is so located as not to interfere with the use of the locks now in place there during its construction. It has been announced that the $9,000,000 appropriated will fall about $7,000,000 short of completing the work of deepening and lengthening on the lines thus far carried out, and in consequence the matter of building the lift locks is held in abeyance.[1]

[1] For engineering and other details of the canal improvement now in progress see Eng. News, Vol. XXXVIII (Sept. 2, 16, and 23, 1897). See also Effect of depth upon artificial waterways, by Thomas C. Clark: Trans. Am. Soc. Civil Eng., Vol. XXXV, pp. 1-40. Also Eng. News, January 6, 1898, for discussion of the question, What shall New York do with its canals?

DESCRIPTION OF THE CANALS NOW IN OPERATION, AND THEIR WATER SUPPLY.

Following are some of the main facts in regard to the principal canals—Erie, Champlain, Oswego, and Black River—now in operation in the State of New York. Similar facts for Oneida Lake Canal, Oneida River improvement, the Cayuga and Seneca Canal, and others, may be obtained by reference to the annual reports of the superintendent of public works.

Length, capacity, and cost of New York State canals.

ERIE CANAL.

	Original canal.	Enlargement.
Length, in miles	363.00	351.78
Lockage, in feet	675.50	645.80
Average burden of boats, in tons	70.00	210.00
Maximum burden of boats, in tons	76.00	240.00
Construction authorized	Apr. 15, 1817	May 11, 1835
Construction completed	Oct., 1836	Sept., 1862
Actual cost of construction	$7,143,789	$44,465,414

CHAMPLAIN CANAL.

Length of canal, in miles	66
Length of feeder, in miles	7
Length of pond, in miles	5
Total, in miles	78
Construction authorized	Apr. 15, 1817
Glens Falls feeder authorized	Apr., 1822
Estimated cost of canal	$871,000
Total cost of canal and feeder to 1868	2,378,910
Total cost, including improvements and enlargements, to 1875	4,044,000

OSWEGO CANAL.

	Original canal.	Enlarged canal.
Length, in miles	38.00	38.00
Lockage, in feet	154.85	154.85
Average burden of boats, in tons	62.00	225.00
Construction authorized	Apr., 1825	Apr., 1854
Construction completed	Dec., 1828	Sept., 1862
Actual cost of construction	$565,473	$4,427,589

Length, capacity, and cost of New York State canals—Continued.

BLACK RIVER CANAL.

Length of canal, Rome to Lyons Falls, in miles	35.00
Length of improved river to Carthage, in miles	42.00
Length of navigable feeder, in miles	10.50
Lockage, in feet	1,082.25
Average burden of boats, in tons	48.00
Construction authorized	Apr., 1836
Construction completed	1849
Actual cost of construction	$3,581,954

EASTERN DIVISION OF ERIE CANAL.

Erie Canal is divided into three divisions, known as the eastern, the middle, and the western. The eastern division embraces the portion of the canal, with its feeders and side cuts, extending from the Hudson River at Albany to the dividing line between the counties of Herkimer and Oneida, and the whole of the Champlain Canal, with its feeders, ponds, and side cuts. The entire mileage of canals, feeders, and river improvements on the eastern division is as follows:

Mileage of eastern division of Erie Canal.

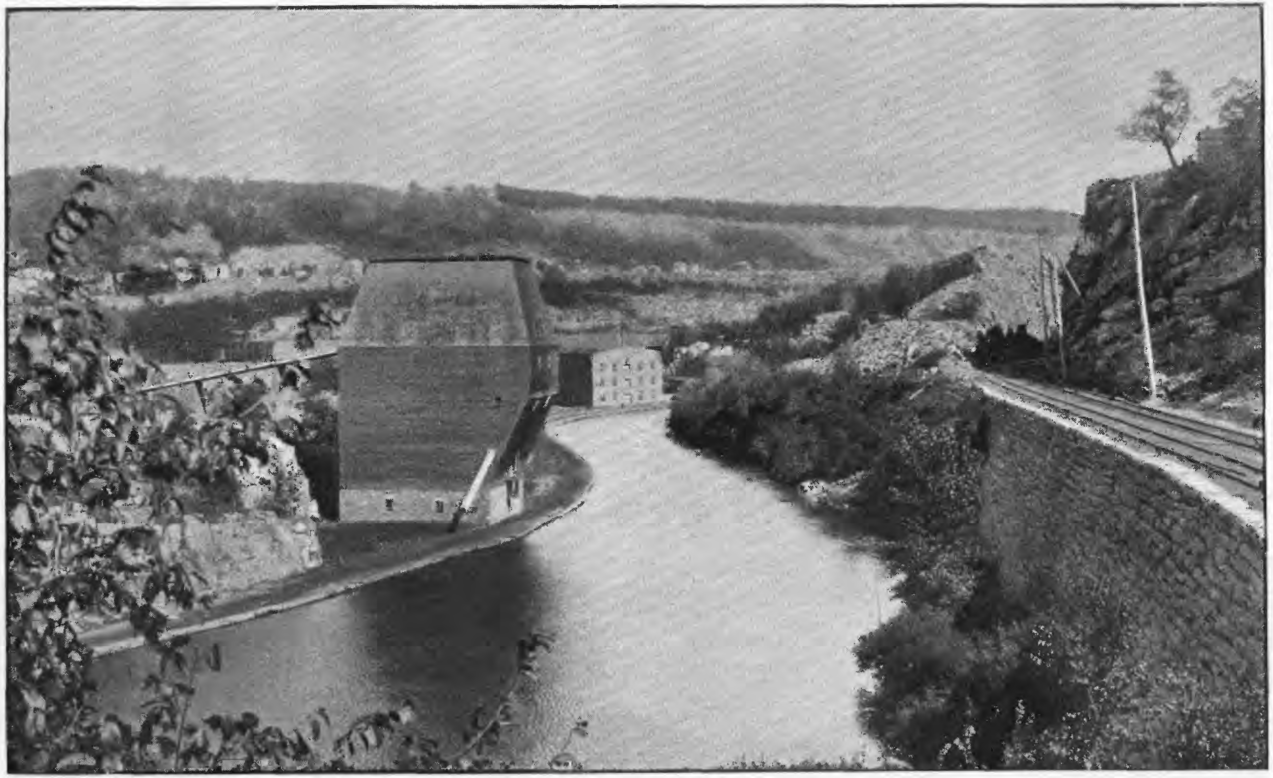
	Miles.
Erie Canal, Albany to east line of Oneida County	106.24
Fort Schuyler and West Troy side cuts	0.35
Albany basin	0.77
Champlain Canal, including Waterford side cut	66.00
Navigable river above Troy dam	3.00
Glens Falls feeder	7.00
Navigable river above Glens Falls feeder dam	5.00
Total	188.36

Mileage of unnavigable feeders of the eastern division of Erie Canal.

	Miles.
Mohawk River at Rexford Flats	0.39
Mohawk River at Rocky Rift	3.92
Mohawk River at Little Falls	0.19
Schoharie Creek	0.63
Total	5.13

WATER SUPPLY OF THE EASTERN DIVISION.

To the west of Little Falls, on the Erie Canal, lies 19.2 miles of the eastern division, supplied from the reservoirs and streams of the middle division East of Little Falls the supply is from Mohawk River, through Little Falls, Rocky Rift, and Rexford Flats feeders, and from Schoharie Creek through Schoharie Creek feeder. As to the quantity of water used on that portion of Erie Canal included in the eastern division very little is known. With the exception of a few thousand cubic feet per minute received from the middle division, the supply is, as just indicated, all derived from Mohawk River and



ERIE CANAL AT LITTLE FALLS, NEW YORK.

its tributary, Schoharie Creek. Thus far no measurements of the actual quantity used have been made. Probably the total diversion amounts in dry weather to from 500 to 600 cubic feet per second. Some of this is returned to Mohawk River by leakage and wastage, but just what proportion is returned, and what finally delivered either into Hudson River at Albany or by the Troy and Fort Schuyler side cuts, is not known. In view of the magnitude of the power development on Mohawk River at Cohoes it appears very desirable that such a determination be made.

The water supply of Champlain Canal is derived from Wood Creek and several small streams to the north of Fort Edward, Glens Falls feeder, Hudson River feeder, from Hudson River itself at Saratoga dam, and from Mohawk River at the Cohoes dam. An investigation of the amount of water diverted from Hudson River for the supply of Champlain Canal was made by the author in the fall of 1895.

As already stated, Champlain Canal is fed from Hudson River by Glens Falls feeder, which connects with the river about 2 miles above Glens Falls and from the Saratoga dam at Northumberland.

The length of Glens Falls feeder, from the guard lock at its head to where it enters Champlain Canal, about 2 miles above Fort Edward, is 6.92 miles. From this point the water in the canal flows both north and south, the total length of canal fed by Glens Falls feeder being 31.81 miles. Fort Edward level, into which Glens Falls feeder delivers water, is a summit level, and hence the water delivered into it, less the losses by percolation, evaporation, etc., is partly discharged into Lake Champlain and partly into Hudson River at Saratoga dam. Champlain Canal crosses through the pond formed by Saratoga dam from the east side to the west of the Hudson and again passes out of the river, taking a full supply therefrom at the village of Northumberland, from which point to Mohawk River at Cohoes the distance is 27.06 miles. The water from this section by passing into the Mohawk finally reaches the Hudson above the Troy dam. The canal crosses Mohawk River at Cohoes, taking water therefrom to supply the section from Cohoes to near West Troy, a distance of 2.36 miles. A small amount of water also passes from Champlain Canal to the Hudson through the Waterford side cut.

Since the construction of Glens Falls feeder there have existed serious leaks though the seamy limestone rock in which the feeder is excavated at and below the village of Glens Falls. It is claimed that the losses through these seams have generally increased, until for several years past they have amounted to about 50 per cent of the total flow into the feeder at the guard lock.

This leakage has been repeatedly complained of by the owners of water power at Glens Falls and several attempts to check it have been made, but without much avail. The river falls 38 feet at Glens Falls, and the owners of the water power there claim that this leakage, which is practically all below the falls, is a detriment to their water power which ought not to exist. In order to determine the amount of this leakage, as well as the relation which it bears to the question of a material increase in the flow of Hudson River by storage, a series of measurements of the flow of the feeder was undertaken early in October, 1895.

Arrangements having been made with the division superintendent to maintain a uniform feed for several days before the measurements began, as well as during the days when they were actually being made, and points established for verifying the uniformity of the flow during the time of the measurements, a series of accurate sections was then made at points both above and below the leakage, and a large number of current-meter readings taken from a footbridge thrown temporarily across the feeder at each section. The results so obtained are as follows:

(1) On October 8, 1895, the flow in the feeder just below the guard lock at the feeder dam, above all serious leaks, was 383 cubic feet per second.

(2) On the same day the flow at change bridge No. 13, about one-half mile from the feeder dam, above all serious leaks, was 364 cubic feet per second.

(3) On October 9 and 10 the flow a short distance below all serious leaks was 213 cubic feet per second.

(4) On October 10 the flow about half a mile farther down was 191 cubic feet per second.

(5) On October 11 the flow just above the locks at Sandy Hill was 182 cubic feet per second.

(6) A section, also taken October 11, in Champlain Canal, a short distance north of where the feeder enters, shows that the amount of water passing to the north at that time was 74 cubic feet per second.

These measurements show that the loss between sections 1 and 5, which may be taken as including about all the losses from the feeder, is 201 cubic feet per second. The water delivered into Champlain Canal is, therefore, only about 47 per cent of the quantity entering the feeder at the guard lock. The measurements also show that of the 182 cubic feet per second actually delivered to Champlain Canal 74 cubic feet per second is diverted to the north, and 108 cubic feet per second, less the loss from evaporation, etc., is returned to the river at the Saratoga dam.

Since the foregoing measurements were made, the enlargement of Champlain Canal has been begun, and its effect, by tearing up the old bottom, will undoubtedly be to decrease considerably the supply of water for the next few years. Taking into account this decrease, as well as the larger losses from evaporation and absorption by vegetation during the summer months, we may place the demands for the enlarged Champlain Canal during the months of canal navigation at the following approximate monthly means:

Water required for the enlarged Champlain Canal.

	Second-feet.
May	553
June	600
July	600
August	600
September	553
October	510
November	495

With the leakage of Glens Falls feeder done away with, the foregoing figures may be reduced about 200 cubic feet per second for each month. For the section of Champlain Canal from Northumberland to Cohoes we may assume the water supply of the enlarged canal at about 255 cubic feet per second in May, October, and November, and at about 280 to 290 cubic feet per second in June, July, August, and September.

MIDDLE DIVISION.

This division comprises that portion of Erie Canal lying between the east line of Oneida County and the east line of Wayne County, as well as Oswego Canal from Syracuse to Oswego, the Baldwinsville side cut, the Cayuga and Seneca Canal, Black River Canal, and other short stretches as indicated in detail below. The following are the lengths in miles of the several sections:

Mileage of the middle division of Erie Canal.

	Miles.
Erie Canal from east line of Oneida County to east line of Wayne County	97.02
Oswego Canal	37.78
Side cuts and slips at Salina	2.02
Slips at Liverpool	.25
Baldwinsville side cut	.59
Cayuga and Seneca Canal	22.99
Black River Canal	35.52
Old Oneida Lake Canal	1.05
Chenango slip	.05
Chemung Canal, original lake level	2.53
Total	199.80

Mileage of river improvements pertaining to the middle division of Erie Canal.

	Miles.
Black River	42.50
Onondaga outlet	.75
Oneida River	20
Seneca River towing path	5.83
Seneca River	Not used.
Ithaca inlet	2.05
Seneca outlet	.17
Total	71.30

Mileage of navigable feeders of the middle division of Erie Canal.

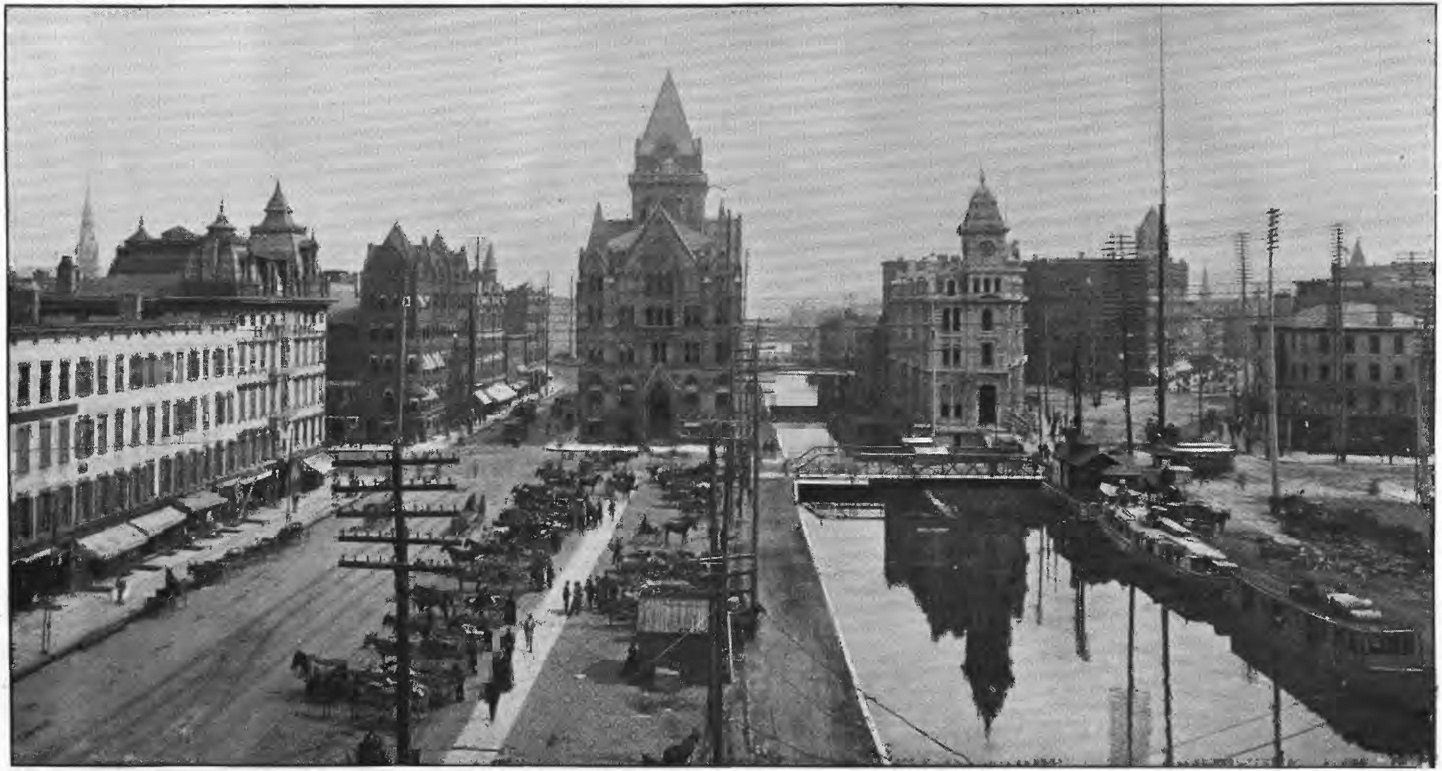
	Miles.
Limestone Creek feeder	0.83
Butternut Creek feeder	1.67
Camillus feeder	1.04
Delta feeder	1.40
Black River feeder	11.29
Total	16.23

The total length of canal, river improvement, and navigable feeders on the middle division is thus found to be 299.08 miles. The following feeders of the middle division are not navigable:

Mileage of unnavigable feeders of the middle division of Erie Canal.

	Miles.
Chenango Canal, summit level	5.31
Leland Pond feeder	.31
Madison Brook feeder	2.99
West Branch feeder	5.83
Bradleys Brook feeder	.67
Hatch Lake feeder	.23
Kings Brook feeder	1.87
Oriskany Creek feeder	.53
Mohawk feeder at Rome	.03
Oneida Creek feeder	2.91
Cowasselon Creek feeder	.40
Chittenango Creek feeder	.28
Cazenovia Lake outlet	.51
Tioughnioga River feeder	1.00
De Ruyter reservoir outlet	.12
Orville reeder	.55
Camillus feeder (unnavigable portion)	.65
Carpenter Brook feeder	.18
Skaneateles Creek feeder	.09
Putnam Brook feeder	.20
Centerport feeder	.18
Owasco Creek feeder	2.10
Lansing Kill feeder	1.80
Sugar River feeder	.14
Canachagala Lake outlet	.16
Total	29.04

Rome level, which is a summit level, extends from lock No. 46 to lock No. 47, a distance of 55.96 miles. The following is the estimated water supply of this level before the beginning of the enlargement now in progress.



ERIE CANAL AT SYRACUSE, NEW YORK.

Water supply of Rome level, Erie Canal.

	Second-feet.
Lelands Pond, Madison Brook reservoir, Eaton Brook reservoir, Bradley Brook reservoir, Hatch Lake, Kingsley Brook reservoir, and Oriskany Creek feed through the Chenango Canal, Oriskany Creek, and Oriskany Creek feeder into the Rome level, 6 miles west of lock No. 46	100
Mohawk River, Black River, Forestport Pond, Forestport reservoir, White Lake reservoir, Chub Lake, Sand Lake, First, Second, and Third Bisby lakes, Woodhull reservoir, Twin Lakes, South Branch reservoir, North Branch reservoir, and Canachagala Lake feed through the Rome feeder and Black River Canal into the Rome level at Rome, 14 miles west of lock No. 46	217
Oneida Creek enters canal through feeder 30 miles west of lock No. 46	17
Cowasselon Creek enters canal through feeder 31.5 miles west of lock No. 46	3
Cazenovia Lake reservoir, Erieville reservoir, and Chittenango Creek enter canal through Chittenango Creek feeder, 41.5 miles west of lock No. 46; average for navigation season about	47
De Ruyter reservoir enters canal through Limestone Creek (Fayetteville) feeder, 50 miles west of lock No. 46; average for the navigation season about	32
Limestone Creek (natural flow) also enters canal through Limestone Creek (Fayetteville) feeder, 50 miles west of lock No. 46	8
Jamesville reservoir enters canal through Orville feeder, 52 miles west of look No. 46; average for navigation season	11
Butternut Creek (natural flow) enters canal through Orville feeder, 52 miles west of lock No. 46	8
Total	443

Jordan level, which is also a summit level, extends from lock No. 50 to lock No. 51 and is 14.903 miles in length. The following feeders are tributary to this level:

Water supply of Jordan level, Erie Canal.

	Second-feet.
Otisco Lake reservoir fed through Camillus feeder into the canal, 4 miles west of lock No. 50	86
Ninemile Creek (natural flow) also fed into canal through Camillus feeder	13
Carpenter Brook feeder	3
Skaneateles feeder	146
Total	248

The following feeders deliver water into the Port Byron level, which extends from lock No. 51 to No. 52, a distance of 7.79 miles:

Water supply of Port Byron level, Erie Canal.

	Second-feet.
Putnam Brook feeder at Weedsport	3
Owasco feeder	69
Total	72

Oswego Canal receives about 167 cubic feet per second from Erie Canal at Syracuse. The balance of its water supply is derived from Seneca and Oneida rivers. The total amounts to about 1,400 cubic feet per second. Seneca and Cayuga Canal receives about 67 cubic feet per second from Erie Canal at Montezuma, and 300 cubic feet per second from Seneca Lake, making a total of 367 cubic feet per second.

The approximate water supply of the middle division of Erie Canal at present may therefore be summarized as follows:

Water supply of the middle division of Erie Canal.

	Second-feet.
Frankfort and Rome level	443
Jordan level	249
Port Byron level	70
Total	762
Oswego Canal:	
Supply from Seneca River	900
From Oneida River	333
Total	1,233
Seneca and Cayuga Canal	300
Grand total	2,295

The present total water supply of middle division may thus be placed, approximately, at 2,295 second-feet.[1]

RESERVOIRS OF THE MIDDLE DIVISION.

As indicated in the preceding statement of the water supply of the middle division, this division has an extensive system of reservoirs, as, for instance, Owasco Lake, the original surface of which has been raised by a dam on the outlet about half a mile below the foot of the lake. Skaneateles and Otisco lakes have also been raised by similar constructions. Proceeding east, the next reservoir is the Jamesville, formed by a dam on Butternut Creek. De Ruyter reservoir is on the dividing ridge, at the extreme head waters of Limestone Creek, and supplied by a feeder from the head waters of Tioughnioga River, a tributary of Chenango River. On Chittenango Creek, the next stream east of Limestone Creek, we find Cazenovia Lake, controlled by a dam at its foot and Erieville reservoir on the extreme head waters.

On the head waters of Oriskany Creek and Chenango River there is an extensive reservoir system, originally constructed for the purpose of supplying the summit level of Chenango Canal, but which has been retained in use for the water supply of the middle division, the water therefrom being conducted to Erie Canal at Utica, through the old prism of Chenango Canal, retained as a feeder, or to Erie Canal at Oriskany, through the natural channel of Oriskany Creek and a short feeder at Oriskany village. The reservoirs on the head waters of Oriskany Creek are Madison Brook and Lelands Pond reservoirs; those on the head waters of Chenango Creek, and which are connected with the summit level of the old Chenango Canal by a feeder

[1] This is a very general statement, and to be taken in connection with a large amount of detailed information in the reports not specifically cited at this time.

several miles in length, are Eaton Brook, Hatch Lake, Bradley Brook, and Kingsley Brook reservoirs.

Reference may also be made to the reservoirs on Black River and its tributaries. These are: Woodhull, Bisby Lakes Nos. 1, 2, and 3, Sand Lake, Chub Lake, White Lake, Canachagala Lake, North Branch Lake, South Branch Lake, Twin Lakes, and Forestport and Stillwater reservoirs. The Bisby Lakes have been abandoned. The details of these reservoirs on Black River, as well as those of all other reservoirs thus far connected for the water supply of Erie Canal, may be obtained from the table on page 166.

WESTERN DIVISION.

The western division of Erie Canal includes the following:

Mileage of the western division of Erie Canal.

	Miles.
Erie Canal from the east line of Wayne County to Hamburg street, in the city of Buffalo	148.92
Five slips in the city of Buffalo, aggregate length	1.60
Genesee River feeder in the city of Rochester	2.25
Total	152.77

The unnavigable feeders of this division are:

Mileage of the unnavigable feeders of the western division, Erie Canal.

	Miles.
Tonawanda and Oak Orchard Creek	11.55
Prism of old Genesee Valley Canal, Cuba reservoir to Rockville	7.65
Prism of old Genesee Valley Canal, Scottsville to Rochester feeder dam	11.00
Total	30.20

The only reservoirs on the western division are the Oil Creek and Rockville reservoirs, originally constructed to feed the summit level of Genesee Valley Canal, and still retained as subsidiary feeders to Erie Canal, their waters being finally discharged into Genesee River and thence taken into the canal through Genesee River at Rochester. The main characteristics of Oil Creek and Rockville reservoirs may be obtained from the table on page 166.

The sources of water supply for the western division are: Lake Erie, at Buffalo; Tonawanda Creek, at Pendleton; Tonawanda and Oak Orchard creeks, at Medina; Allens Creek, through the prism of the old Genesee Valley Canal, from Scottsville to Rochester; the Genesee River at Rochester.[1]

[1] The foregoing statements as to length, water supply, and reservoirs of Erie Canal, while covering only a small amount of the total data, are still as much as can be given at this time. Full information may be obtained by reference either to the annual reports of the State engineer and surveyor from 1850 to 1896, inclusive, or of the superintendent of public works from 1878 to 1896, inclusive. Previous to 1878 the reports of the canal commissioners may also be consulted for a large amount of useful information.

Reservoirs for the water supply of Erie Canal.

Reservoir.	Date of completion.	Elevation.	Distance to canal.	Flow-line area.	Height of flow line.	Average area.	Average depth.	Capacity.	Original cost.	Cost per million cubic feet.
		Feet.	*Miles.*	*Acres.*	*Ft.*	*Acres.*	*Feet.*	*Cubic feet.*		
ROME LEVEL—ERIE CANAL		428								
Woodhull	1859	1,854	25.0	1,236	16	1,118	18.0	876,550,000	$24,089	$27.47
Bisby Lake, No. 1 *a*	1881	2,018	27.8	156	4					
Bisby Lake, No. 2	1881	2,018	27.0	204	4		3.5	40,000,000		
Bisby Lake, No. 3	1881	2,006	26.0	41	4					
Sand Lake	1872	1,808	24.0	344	18	306	15.0	199,879,822	5,505	27.71
Chubb Lake	1881	1,599	20.5	530	22	200	4.0	34,848,000	8,134	233.43
White Lake	1881		18.0	332	5	296	5.0	64,468,800	5,102	79.27
Canachagala Lake	1881		32.0	347	4	320	4.0	55,756,800	1,456	26.11
North Branch Lake	1857	1,821	25.5	423	28	277	28.0	337,851,360	34,637	102.22
South Branch Lake	1859	2,019	26.0	518	26	372	26.0	421,312,320	20,168	47.87
Twin Lakes	1881		22.0	212	6	175	8.0	60,984,000		
Forestport Pond	1853	1,124	10.5	160			2.0	13,921,920		
Forestport reservoir	1894	1,139	12.5	793	21	700	7.0	212,444,000		
BOONVILLE LEVEL—BLACK RIVER CANAL		1,121	25.0							
JORDAN LEVEL—ERIE CANAL		408								
Skaneateles Lake	1844	864	9.0	8,320			9.0	2,174,512,000	14,928	6.87
Otisco Lake	1869		12.0	2,200			10.0	784,000,000	43,753	55.81
PORT BYRON LEVEL—ERIE CANAL		403								
Owasco Lake	1866	704	12.0	680			5.0	1,481,040,000	36,296	25.59
ROCHESTER LEVEL—ERIE CANAL		508								
CUBA LEVEL—GENESEE VALLEY CANAL		1,489								
Oil Creek	1858		91.0	605	65	525	15.0	435,738,000	69,216	158.85
Rockville	1842		8.30			72	20.0	18,200,000	7,711	423.68
ROME LEVEL—ERIE CANAL		428								
Erieville	1850	1,577	20.0	340	46		21.5	318,424,000	36,837	115.68
Cazenovia Lake	1857	1,176	10.0	1,778			4.5	348,523,000	10,885	31.23
De Ruyter	1863	1,276	25.0	626			18.5	504,468,000	78,761	156.13
Jamesville	1874	585	6.0	252		240	16.0	170,000,000	150,000	882.35
Hatch Lake *b*	1836		36.0	134	15		10.0	58,370,400	4,464	76.47
Eaton Brook *b*	1836		38.0	254	60	244	50.0	553,212,000	28,059	50.72
Bradley Brook *b*	1836		35.0	134	30		25.0	145,926,000	16,159	110.73
Leland Pond *b*	1836		25.0	173	13	150	8.0	59,287,040	8,894	150.02
Madison Brook	1836	1,127	29.0	345	55	255	45.0	460,647,000	36,301	78.80
Kingsley Brook	1867		33.0	113			20.0	98,445,600	80,481	817.54

a Supply to canal through Forestport Pond and Black River Canal.
b Supply to canal through Oriskany Creek feeder.

SHIP-CANAL PROJECTS AND WATER SUPPLY.

By virtue of the geographic position of New York, with the Great Lakes on its western boundary and the Atlantic Ocean on its eastern, and with the commercial capital of the Western Continent as its chief city, all discussions of deep waterway projects from the Upper

Great Lakes to the seaboard are, necessarily, chiefly discussions of the water resources of New York. It is proper, therefore, that the several deep water projects now under discussion should be briefly noticed in a report of this character.

In February, 1895, Congress by a joint resolution authorized a preliminary inquiry concerning deep waterways between the Great Lakes and the ocean, and provided that the President should appoint three commissioners to make such inquiry. The President, under this resolution, appointed Prof. James B. Angell, of Ann Harbor, Michigan; John E. Russell, of Leicester, Massachusetts, and Lyman E. Cooley, of Chicago, Illinois. The report of the commission, as published in 1897, includes a large amount of valuable information in regard to a deep waterway from the Upper Great Lakes to the Atlantic seaboard. In regard to the State of New York, it has been pointed out by Mr. Cooley that nature has indicated two feasible routes for such a canal. The first of these is the Oswego-Mohawk-Hudson route, extending from Oswego through the valley of Oswego and Oneida rivers, and thence across the divide to the Mohawk, thence through Mohawk Valley to a point on the Hudson in the vicinity of Troy, and so on through Hudson River to tide water at New York. One objection to this route is the lockage over the summit between Lake Ontario and Mohawk Valley. Another objection is the absorption of a large quantity of water in central New York for the supply of the summit level of the canal, and which probably can be more effectively used in manufacturing; that is to say, the State of New York, by developing its manufacturing resources to their fullest extent, can realize more return from manufacturing than from the use of its inland waters for purposes of internal navigation of any kind whatever. It may be pointed out in passing that the Oswego-Mohawk-Hudson route would utilize the great natural highway which has been an easy passage to commerce from the early days of settlement on the Atlantic coast.

The second natural route through the State of New York is by way of St. Lawrence River to the head of Coteau Rapids, where the low-water level of Lake St. Francis is 153.5 feet above tide, or 68.5 feet above the low-water level of Lake Champlain. On this plan a canal would be constructed from Coteau Landing to the head of Lake Champlain, near Rouses Point, this section requiring cutting through a summit about 50 feet in height. Lake Champlain would then be utilized to Whitehall, from which point a canal would be cut through the valley leading from Whitehall to Hudson River at Fort Edward, the elevation of the water surface of the Hudson a few miles below Fort Edward being somewhat less than the low-water elevation of Lake Champlain. After reaching the Hudson the work would include the deepening of that stream to deep water, a few miles below Albany. Either of the foregoing projects would further include the construction of a ship canal connecting Lakes Erie and Ontario.

The advantage of the St. Lawrence-Champlain-Hudson over the Oswego-Mohawk-Hudson route is that the lockage would be all in one direction; that is, eastward-bound vessels would lock down all the way from Lake Erie to New York. Its disadvantages are increased length and the location of the canal connecting St. Lawrence River with Lake Champlain in Canadian territory. In regard to increased length, it is claimed that not much more time would be required in traversing it than would be consumed in locking over the Oswego-Mohawk summit.

As to the capacity of the proposed canal, the Deep Waterways Commission points out in its report that such a canal, if built, should be so carried out as to be adequate for vessels of the most economical type, not only for coasting or domestic trade but also for the foreign movement, so that commerce may be carried on directly between lake ports and other domestic and foreign ports without transshipment. Taking into account various other conditions, the commission believes that the requirements of the present demand a limiting draft in the proposed canal of 27 or 28 feet; hence, in concluding the general discussion, the commission recommends the securing of a channel of a navigable depth of not less than 28 feet.

The commission also says that, starting from the heads of Lakes Michigan and Superior, the most eligible route for a deep waterway is through the several Great Lakes and their intermediate channels and the proposed Niagara ship canal to Lake Ontario, and that the Canadian seaboard may then be reached from Lake Ontario by the way of St. Lawrence River, and the American seaboard reached from Lake Ontario by way of either the Oswego-Mohawk-Hudson route or the St. Lawrence-Champlain-Hudson route. The Deep Waterways Commission was not authorized to make any considerable expenditure for surveys, and hence the conclusions announced are to some degree tentative. In view of the uncertainty as to final cost, it is recommended that the alternative routes from Lake Ontario to the Hudson be subject to complete survey in order to obtain a full development of the governing economic considerations, as well as to determine their relative availability.

The commission also recommends a moderate control of the level of Lake Erie and of Niagara River above Tonawanda by dam, but leaves the practical details undetermined in the absence of a full understanding of the physical conditions.

The river and harbor act of June 3, 1896, directs the Secretary of War to cause to be made accurate examinations and estimates of the cost of constructing a ship canal by the most practicable route, wholly within the United States, from the Great Lakes to the navigable waters of Hudson River, of sufficient capacity to transport the tonnage of the lakes to the sea. Under the provisions of this act a report was submitted by Maj. Thomas W. Symons, of the Corps of Engineers, dated June 23, 1897.[1]

Major Symons states that there are three possible routes for the ship canal, entirely within the territory of the United States, from the Great Lakes to the navigable waters of the Hudson, as follows:

(1) From Lake Erie via the upper Niagara River to the vicinity of Tonawanda or La Salle; thence by canal, with locks, either to the lower Niagara at or near Lewiston, or to some point on Lake Ontario; thence through Lake Ontario to Oswego; thence up Oswego and Oneida rivers to Oneida Lake, and through Oneida Lake; thence across the divide to Mohawk River, and down that river to the Hudson at Troy; thence down the Hudson. This he designates as the Oswego route. From Oswego to Hudson River it is, in effect, the Oswego-Mohawk-Hudson route, already described.

(2) To follow either the line of Erie Canal from Lake Erie to the Hudson, or this line so modified as to provide for a continuously descending canal from Lake Erie to the Hudson. This he designates as the Erie Canal route.

(3) This route coincides with the first from Lake Erie to Lake Ontario, but runs thence through Lake Ontario to St. Lawrence River and down said river to some point near Ogdensburg; it then crosses the State of New York to Lake Champlain and up that lake to Whitehall; and thence follows in general the route of the Champlain Canal to Hudson River at Troy. This route, however, Major Symons pronounces impracticable.

There is also discussed a fourth route—the St. Lawrence-Champlain—all of which, except a small portion, is within the United States. This route would be via Niagara Falls, Lake Ontario, the St. Lawrence, Caughnawaga, and Richelieu rivers, Lake Champlain, and the Hudson.

The opinion is expressed that the best route for the contemplated ship canal is that via Niagara River, Lake Ontario, Oswego and Oneida rivers, Oneida Lake, and Mohawk and Hudson rivers, and that to build such a canal by any of the possible routes mentioned would, at a rough estimate, cost $200,000,000, the exact figure depending very largely upon the action of the State of New York in regard to the State canals, feeders, reservoirs, etc.; and that to maintain the canal and to keep it in repair, including the maintenance of river channels, reservoirs, and feeders, would cost, at a rough estimate, $2,000,000 a year. The statement is made that a ship canal would be of no special military value, and that its construction is not worthy of being undertaken by the General Government because the probable benefits to be derived from it would not be commensurate with the cost.

Major Symons further expresses the opinion that Erie Canal, when enlarged under the present plans of the State of New York, may

[1] See Ann. Rept. Chief of Engineers for the fiscal year ending June 30, 1897.

give, if State restrictions are removed, commercial advantages practically equal to those to be derived from the proposed ship canal, and that if Erie Canal be further improved by enlargement to a size sufficient for 1,500-ton barges, making such alterations in alignment as to give a continuously descending canal all the way from Lake Erie to the Hudson, and canalizing Mohawk River, the improved canal, navigated by barges, would render practicable the transportation of freight between the East and the West at a lower rate than by a ship canal navigated by large lake or ocean vessels. The difficulty of navigating large vessels through long, shallow canals is the loss of time and the consequent great increase in the pro rata expense account, as compared with the actual amount transported between termini. Major Symons is also of opinion that the enlargement of Erie Canal on these lines is a project worthy of being undertaken by the General Government, because the benefits to be derived would be commensurate with the cost, which he estimates at approximately one-fourth that of a ship canal, or $50,000,000.

Space will not permit abstracting in detail these several interesting reports on ship canals across the State of New York. To understand the subject in all its bearings, reference must be made to the original reports.

The Oswego-Mohawk-Hudson route is discussed in a report by Albert J. Himes in the Report of the State Engineer and Surveyor for 1895.[1]

In this report Mr. Himes expresses the opinion that a sufficient water supply could not be obtained for a high summit level across the divide, and hence the canal must be cut from the level of Oneida Lake through to the corresponding level in Mohawk Valley. In this way he proposes to use Oneida Lake as a storage reservoir from which to discharge water both ways to Oswego and Mohawk rivers. By this plan the surface of Oneida Lake would be raised 10 feet, furnishing 1,100 second-feet continuously for seven months. Without going into detail, the writer can not but believe that the water supply estimated by Mr. Himes is not entirely adequate for the supply of such a canal as has been proposed. If such a canal is constructed, the experience gained in the last seventy-five years ought to teach the danger of small economies in designing the water supply. Experience shows that canal water supplies must be made ample, as otherwise a shortage will result sooner or later.

In a paper on an enlarged waterway between the Great Lakes and the Atlantic seaboard, published by William Pierson Judson, the water supply of the summit level of the Oswego-Mohawk-Hudson route is discussed at length. Mr. Judson considers that it would be entirely proper to take whatever deficiency there might be from the

[1] See report on the Enlarged canal via the Oswego route, by Albert J. Himes, resident engineer, Eastern division, New York State canals. In Ann. Rept. State Eng. and Surv. for the fiscal year ending September 30, 1895.

head waters of the Black River, reservoirs in addition to those now existing being constructed on the Beaver and Moose rivers, tributary to the Black, for the purpose of furnishing this water. He recognizes that the item of adequate water supply for such a canal is vital, and frankly states that if surveys and thorough investigations were to show that the demand for water for such a canal is beyond the capacity of the sources of supply, then the Oswego-Mohawk-Hudson route would be shown to be impracticable, although, as an alternative proposition, he states that it would be entirely practicable to supply the summit level of such a canal from Lake Erie. This, it is pointed out, can be accomplished by a feeder branch taken from the present Erie Canal near Macedon, 12 miles west of Newark, where Erie Canal is now 35 feet above the Rome level. The proposed feeder, instead of stepping down, as does the Erie Canal, can be swung off to the south on higher ground at the necessary elevation, passing along the south side of Clyde River and crossing Seneca River near the Cayuga Lake Outlet. Seneca River is narrowest here, and the feeder could be carried across it in an open trunk on a 40 to 50 foot trestle about 2 miles long. Such a feeder 8 feet in depth and 38 feet in bottom width would carry 1,000 cubic feet per second, or enough, according to Mr. Judson, to meet the assumed needs. On this point, however, the author differs; he can not but think that the summit-level supply as estimated by Mr. Judson at 1,000 cubic feet per second is much too small. Mr. Judson's discussion of the deep-waterway question is further open to criticism in that he does not adequately recognize the economic value of the New York water supplies for use in manufactures.

In a paper read before the American Society of Civil Engineers in 1884, Elnathan Sweet proposed a ship canal through to Lake Erie via present line of the Erie Canal, except that its alignment be rectified to follow the line of the feeder, as proposed by Mr. Judson. The difficulties of making a ship canal on this line are, however, so great that many engineers have considered it absolutely out of the question.[1]

A canal on the Oswego-Mohawk-Hudson route 28 to 30 feet in depth, with corresponding surface and bottom dimensions, will probably absorb all available water of central New York, as well as a considerable portion of Black River. The water powers on Mohawk River at Cohoes will necessarily be made subservient to the exigencies of such a canal, although Mr. Judson, in the paper already referred to, has pointed out how valuable these water powers would be for seven or eight months of the year to the manufacturing cities of the Mohawk Valley. Under this head we may, however, inquire as to how the water power for only seven months of the year would be of any special

[1] See Radical enlargement of the artificial waterway between the Lakes and Hudson River, by Elnathan Sweet: Trans. Am. Soc. Civil Eng., Vol. XIV, pp. 37-139.

value to the city of Cohoes, where, owing to the kind of manufacturing, continuous power three hundred and ten days in the year is required. Cohoes had a population in 1890 of 22,509, and is stated to have grown considerably since, so that in 1897 the population is probably in excess of 25,000. This great development is a result of wise management of the water power, without which there is no reason to suppose that the area on which the city stands would have any greater value than that of the surrounding farming region. A proposition to interfere seriously with the water power at Cohoes can only be looked on by the author as most extraordinary. Indeed, not the least extraordinary feature of the present agitation for ship canals across the State of New York is the entire lack of appreciation—so far as the discussion indicates—of the value to the State of New York of its inland waters.

Aside from the report of Major Symons, the discussion has thus far apparently proceeded on the supposition that the taking of inland waters for navigation purposes was a matter on a par with the taking of agricultural lands for right of way, the economic value of the water for power purposes and the resulting effect on the internal development of the State having thus far been almost entirely ignored.

What the people of the State of New York need to consider first of all is whether the inland waters are not now worth more for manufacturing than they can possibly be worth for navigation purposes. If after investigation it is shown that the water will produce greater income to the people of the State in manufacturing than it will in operating such a canal, then from mere commercial considerations the people ought not to consent to the construction of such a canal. Without having the data at hand for a full discussion, the author, after giving the matter careful consideration, is of opinion that the State of New York can not afford to forego the possibility of developing its manufacturing interest in order to furnish water for the summit level of the proposed Oswego-Mohawk-Hudson deep-water canal. At any rate we should know just what results may be expected before embarking in the enterprise. If, however, after full investigation it appears that the canal water supply can be obtained and the manufacturing interests protected, no reasonable objection can be urged.

In order to justify the construction of the ship canal as a commercial proposition, the saving on the transportation of an estimated annual tonnage of 24,000,000 tons over the cost of its transportation by existing means and methods must, at least, equal the interest on the cost of the canal plus the annual cost of maintenance and operation. The first cost is taken at $200,000,000, with the maintenance at $2,000,000 per year. Assuming an interest charge of 3 per cent, the annual interest plus the maintenance becomes $8,000,000, which sum represents the annual expense of the proposed ship canal connecting the Great Lakes with the Atlantic seaboard. As regards the State of New York, there should be added to this amount a sum representing the decrease in wealth in central New York due to the absorption of the inland waters of the State away from manufacturing interests in favor of navigation interests. As a rough estimate the author places such decrease at not less than $5,000,000 per year, although the decrease would probably be much greater than this, but in the absence of data for full discussion he places it at a conservative figure, which can not well be gainsaid. On the other hand, if the international St. Lawrence-Champlain-Hudson route were to be constructed, not only would this source of loss be entirely eliminated, but since that plan proposes to deliver water from St. Lawrence River into Lake Champlain, and thence by a through cut from Lake Champlain to Hudson River, there would be delivered into Hudson River a considerable quantity of water which would be available for power at Saratoga dam, Mechanicville, and Troy. This ship-canal project thus increases rather than decreases the productive capacity of the State. Moreover, it is probable that the St. Lawrence-Champlain-Hudson route can be constructed somewhat more cheaply than the Oswego-Mohawk-Hudson route.

Without wishing to present the foregoing as in any degree a final conclusion, the author can not but think that it is the broad view to take of the question. At any rate, this view presents a line of investigation which ought to be pursued to a conclusion before the final decision is made.

LOSS OF WATER FROM ARTIFICAL CHANNELS.

The large amount of canal construction in New York State has necessitated, in order to provide ample water supplies, the collection of considerable information as to the various sources of loss of water to which artificial channels are subject. Some of the more interesting results may be briefly referred to.

The original Erie Canal was constructed with the water surface 40 feet wide, the bottom width 28 feet, and the depth 4 feet. In 1824 measurements of the loss from filtration and evaporation were made by Mr. John B. Jervis on the eastern division and by Mr. David S. Bates on the western division. Mr. Jervis states that his measurements were made in the original Erie Canal, between the first locks below the village of Amsterdam and the aqueduct below Schenectady, a distance of 18 miles. This section was constructed mainly through an alluvial soil, containing a large portion of vegetable matter. In some places this soil was very leaky, owing probably to the decay of roots, although the greater portion retained water very well. There was a considerable quantity of gravel and slaty soils. He states that the quantity of water lost in this 18-mile section was very uniform, and averaged 125 cubic feet per mile per minute.[1]

Mr. Bates states that his measurements in 1824 showed that a mile of new canal, such as Erie Canal then was between Brockport and Ninemile Creek, would require 1.7 cubic feet of water per mile per second in order to supply the losses from filtration, leakage, and evaporation.[2] The following are some of the details of Mr. Bates's measurements in 1824:

On 79 miles of canal and feeder, comprising 20 miles of canal from Rochester to Brockport, 57 miles from Rochester to Cayuga, and 2 miles of feeder, the supply was 8,000 cubic feet per minute, or 121.66 cubic feet per mile per minute. The months are not stated, although it may be inferred that these observations are averages of the navigation season.

Mr. Bates further states that in August, 1824, he found a total use for the 20 miles from Rochester to Brockport of 2,100 cubic feet per minute, equal to 105 cubic feet per mile per minute. This section of the original Erie Canal was considered to be entirely free from leakage at the structures, and the measured losses are therefore taken as those due only to percolation, absorption, and evaporation.[3]

In August, 1839, Henry Tracy and S. Talcott, acting under instructions from W. H. Talcott, resident engineer of the fourth division of Genesee Valley Canal, made a series of observations along the line of Chenango Canal, with a view of determining the evaporation, filtration, and leakage at the mechanical structures, and whatever else might be useful in the designing of the water supply of the summit level of Genesee Valley Canal.

For the purposes of the measurements they selected a portion of the canal extending from the north end of the summit level to Erie Canal, 22 miles in length, on which the total supply on August 31 was found to be 39 cubic feet per second. The leakage and waste at aqueducts, waste weirs, and at lock No. 1 at the northern end, were found to be 15 cubic feet per second, thus leaving the evaporation and filtration on 22 miles at 24 cubic feet per second, equivalent to 1.09 cubic feet per mile per second. It may be observed, however, that a measurement made at the end of August would probably not show a maximum of either evaporation or absorption by vegetation. Estimating these elements at the maximum, we may assume from 1.33 to 1.67 cubic feet per mile per second as a more reliable quantity than the 1.09 cubic feet per mile per second here actually observed.

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[1] Report of John B. Jervis to the canal commissioners, on the Chenango Canal. Ann. Rept. Canal Com. (1834). Ass. Doc. No. 55, p. 54.

[2] Report of David S. Bates to the canal commissioners, on the Chenango Canal (1830). Ass. Doc. No. 47, p. 31.

[3] See report of F. C. Mills in relation to the Genesee Valley Canal (1840). Ass. Doc. No. 26, p. 26. See also report of W. H. Talcott in the same document. These two reports contain a summary of all that had been done in the way of measurements of the various losses now under discussion up to that time, as well as a number of references to foreign data.

Messrs. Tracy and Talcott also measured the leakage and waste at the various mechanical structures, etc., which were as follows: Leakage at structures, 220 cubic feet per minute; waste at waste weirs, 204 cubic feet per minute; leakage at lock No. 1, at the north end of the section, 479 cubic feet per minute. This amount, Mr. Talcott remarks, was so much greater than at any other lock on the canal as to induce the belief that the gates were not properly closed at the time of measurement. At lock No. 69 on the same canal, the leakage was 382 cubic feet per minute from an 8-foot lift.

Mr. Talcott's report is very able, and presents forcibly all the data at hand at that time. It may be said that the data which he gave fixed the following quantities as fairly covering the various losses to which artificial waterways of the dimensions of the original canals of this State are subject:[1]

(1) Loss by filtration, absorption, and evaporation, 100.0 cubic feet per mile per minute. With retentive soils this could be reduced to from 60 to 70 cubic feet per mile per minute. Mr. Talcott fixed on 66 cubic feet per mile per minute for Genesee Valley Canal, which was largely built through heavy soils, but this was subsequently found too small.

(2) Leakage at mechanical structures; for locks of 11 feet lift, 500 cubic feet per minute; for leakage and waste at each waste weir, 30 cubic feet per minute; for a wooden-trunk aqueduct, an amount depending on the length of the structure, but as an average, 0.35 of a cubic foot for each linear foot of trunk may be taken.

In response to a resolution of the canal commissioners of April 12, 1841, Mr. O. W. Childs, then chief engineer of Erie Canal, prepared a report on the water supply of the western division with reference to the enlargement then in progress.[2] In this paper Mr. Childs gives the results of measurements made by himself in 1841 of losses from filtration, absorption, evaporation, and leakage on the original Erie Canal between Wayneport, in Wayne County, and Pit Lock, which corresponded to lock 53, near Clyde, of the present canal. He also gave the result of measurements made by Alfred Barrett between Pittsford and Lockport.

Mr. Childs's measurements were for a section of the canal 36.02 miles in length. On the Palmyra level, for a distance of 8.34 miles, where the soil is open and porous the measurements showed a loss of 1.81 cubic feet per mile per second. On the Clyde level with a more retentive soil the losses from filtration, absorption, and evaporation were, for a distance of 27.68 miles, only 0.59 cubic feet per mile per second. The entire loss, including leakage, was, for the whole distance, 1.40 cubic feet per mile per second. These measurements were made for

[1] The quantities here given apply to canals 40 feet by 28 and 4 feet deep, and with locks 90 feet in length and 15 feet in width and 8 to 10 feet lift.

[2] See Supply of water required for the canal between Lockport and the Seneca River, by O. W. Childs: Ann. Rept. Canal Com. (1848). Ass. Doc. No. 16, pp. 141-175.

a term of thirty-three days, from July 30 to August 31, inclusive. Measurements were also made in June, early in July, and in the following October, from which the conclusion was derived that demands were greater and the supply less for the time during which the foregoing observations were taken than during any other portion of the season.

Mr. Barrett's measurements were made at various points on the original canal between Pittsford and Lockport, and repeated each day from July 17 to September 30, inclusive. They showed an average loss for the whole period of 73.0 cubic feet per mile per minute. Assuming the same ratio of loss between Pittsford and Wayneport, there resulted, for the entire distance of 122 miles from Lockport to Pit Lock, an average loss of 67 cubic feet per mile per minute. Mr. Childs states that an addition to the foregoing quantity should be made as an allowance for springs and several small streams entering the canal which could not be measured. Making such additions he concludes that 1.42 cubic feet per mile per second should be taken as the total quantity consumed on the 122 miles of canal under consideration, which is equivalent to a total of 173 cubic feet per second. It is stated in the original reports that the supply of water was ample for all the purposes of navigation during these measurements.

Comparing Mr. Childs's measurements of 1841 with those made by Messrs. Jervis and Bates in 1824, one point of great practical utility is strongly brought out, namely, as to the excess of loss of water in new canals over those some time in use; thus Mr. Bates found in 1824, on the same reach of canal as was measured by Mr. Childs in 1841, a total loss of from 1.68 to 1.75 cubic feet per mile per second. It may be assumed that the springs and streams allowed for by Mr. Childs were delivering into the canal in 1824 the same as in 1841, at least 0.17 to 0.25 cubic feet per mile per second. We have, then, as the total supply in 1824 from 1.92 to 2.00 cubic feet per mile per second. Adopting the latter figure as a maximum to compare with Mr. Childs's figure of 1.42 cubic feet per mile per second, as found in 1841, the conclusion is reached that the decrease in the loss by filtration—due presumably to the gradual silting up of the bottom—is something like 0.75 cubic feet per mile per second.

This conclusion may be applied to the conditions of the Erie Canal enlargement now in progress, in which it is proposed to excavate 1 foot from the bottom of many of the levels. The effect of this will be to remove the silt accumulations of many years, thus placing the bottom of the canal, as regards porousness and consequent percolation and filtration loss, in the same condition as when constructed. This consideration alone indicates the necessity of making the water supply of the enlarged canal liberal in order to answer the demands of the first few years while the bottom is again attaining a fixed condition.

Under this head it may be remarked that the experience of seventy-five years in the operation of the New York State canals has thoroughly shown the futility of any attempt at excessive economy in water supply. In the absence of systematic information as to yield of streams, the general tendency has been to overrate the summer flow, with the result of shortage frequently at points where the supply was believed to be ample. The chief sources of such shortage may be enumerated as follows:

(1) The great variation in the yield of drainage areas from year to year, by reason of differences in the rainfall, humidity, and temperature.

(2) The cutting off of forests, which has increased somewhat the spring-flood flows and decreased the summer flow.

(3) The systematic drainage of large areas, which has also tended to increase the flood flows and decrease the summer flows.

(4) The growth of aquatic plants on long levels and the formation of sand bars in the canal, which have tended to decrease the amount passing.

Among minor sources of loss, evaporation and absorption by growing plants may be mentioned, both of which vary somewhat in different years, although neither can be considered a serious source of loss. A number of other measurements of the losses from the original Erie Canal are recorded in the reports, but the foregoing are sufficient for present purposes.[1]

A study of all the measurements in detail shows that in an artificial channel of the dimensions of the original Erie Canal, and constructed on the American system, there should be provided at least 80 to 100 cubic feet per mile per minute, exclusive of water for filling and for lockages.

Using the data of the measurements of 1841, Mr. Childs arrived at the water supply of the enlarged canal of that day in the following manner: It was assumed that the loss by filtration through the bottom and sides of the canal would be as the square root of the pressure or depth of the water, and as the area of the surface pressed. Proceeding on this assumption, he computed the quantity required to supply the losses from filtration, leakage, and evaporation (in the enlarged canal, 1840 to 1860), at 3.17 cubic feet per mile per second. This figure was subsequently substantially adopted for the entire enlarged canal, and, with the exception of a few special cases, is still in use.

Adding the amount required for lockages at lock 53, Mr. Childs placed the entire supply for the western division, from Lockport to the east end, at 3.48 cubic feet per mile per second, or at a total of 424 cubic feet per second for 122 miles of canal.

The canal enlargement now in progress contemplates an increase in

[1]Ass. Doc. (1840), No. 96, p. 26; also Ass. Doc. (1842), No. 24, p. 37.

depth from 7 to 9 feet. Taking into account the results of the measurements on the original Erie Canal, as well as those made by Mr. Childs on the enlarged canal of 1840 to 1860, it has been concluded that the proper figure for water supply on the western division, to which the studies thus far specially refer, should be taken at from 4.17 to 4.5 cubic feet per mile per second.[1]

As to the use of water for lockage, leakage of gates, drawing and swelling of boats, and for turbine water wheels to operate gate-lifting machinery, reference may be made to the Annual Report of the State Engineer and Surveyor for 1889, where data covering these different points may be found.

Ordinarily, the flow of a natural drainage channel increases farther down the stream. The outlet of Skaneateles Lake, however, appears to present an opposite example—that is to say, there is less water flowing at the mouth of the stream than at its head. This statement is derived from a report on the water supply of the middle division of Erie Canal, made in 1862,[2] according to which measurements were made by Mr. S. H. Sweet of the flow through the natural channel of the Skaneateles Outlet, 10 miles in length, discharging into the Erie Canal at Jordan. Mr. Sweet's measurements, which were continued through the dry season of 1859 and the entire season of navigation, apparently indicated a loss of water of more than 3,000 cubic feet per minute in this natural channel. The detail, however, is lacking, and probably before accepting this as a fact the measurements made in 1859 should be verified.

USE AND VALUE OF WATER POWER.

WATER POWER OF ERIE CANAL.

When Erie Canal was first constructed the policy was adopted of leasing the so-called surplus waters for power purposes. Under the terms of the act of 1825, leases were made during 1826 and subsequent years to a number of persons at Black Rock, Lockport, and other localities.

POWER AT BLACK ROCK.

The granting of these leases and the resultant development of large manufacturing interests at several points have raised certain economic questions which will now be briefly discussed. The water power at Black Rock, for which several leases were granted, may be first mentioned. This power is created by the difference in level between the water in Erie Canal and Black Rock Harbor and that in Niagara River outside the harbor wall, this difference of water level

[1] The foregoing statements in regard to measurements of water supply of Erie Canal are abstracted from a report on the water supply of the western division of the Erie Canal, by the author, and are to be found in Appendix I to the Ann. Rept. of the State Eng. and Surv. for the fiscal year ending September 30, 1896.

[2] See Ann. Rept. of State Eng. and Surv. for the fiscal year ending September 30, 1862, pp. 402, 403.

amounting to from 4 feet to 4.5 feet. As measured in the spring of 1896, at a point near the ship lock, it was about 4 feet. According to the report of the assembly committee of 1870, as referred to in the footnote, there were formerly ten mills in operation at Black Rock, using 2,744 second-feet of water. The power developed by these mills, and all operating at full capacity, is estimated at not exceeding 520 horsepower. Owing to the decline of the milling business in New York State a number of these mills have passed out of existence.

The four mills still in existence require about 1,200 cubic feet of water per second to operate them at the full capacity of the wheels now in place.

The use of water by the Black Rock mills has always been a detriment to navigation. When all were running the amount of water actually drawn through the canal and harbor for their supply, and for the supply of the canal to the east of Buffalo, was fully 3,300 cubic feet per second.[1]

When all the Black Rock mills were in operation the great draft of water so obstructed the navigation that the legislature finally authorized the construction of a division wall in Black River Harbor, by which it was expected that the water supply for the mills would be entirely taken from the harbor, leaving the channel of the canal pretty nearly free for the purposes of navigation; but after the greater part of the wall was completed it was ascertained that because of the silting of the upper harbor with sewage mud, as well as drifting sand from the lake, there would be difficulty in obtaining the full supply for the mills through the harbor, without extensive dredging. The division wall was, therefore, never completed, two gaps, amounting, in the aggregate, to several hundred feet, having been left below Terry street. There was thus an expenditure of about $350,000 for the benefit of the milling interests which is entirely without effect for lack of completion. Under the present conditions, however, of entire decline of the Black Rock milling interests, there is, of course, no reason why the wall should be completed, and the matter is discussed here at all merely for the purpose of bringing out clearly the struggle between the navigation interests and the manufacturing interests, which has been in progress in New York State for the last seventy-five years.

POWER AT LOCKPORT.

At Lockport the construction of the Erie Canal through the mountain ridge created a fall of 58 feet at a single point, and since the use of water for lockage purposes is only a small part of the whole flow. The balance required to feed the canal to the east of Lockport is necessarily discharged around the locks into the lower canal by means of

[1] The assembly committee of 1870 give the following figures as then applicable: Lower Black Rock mills, 1,887 second-feet; upper Black Rock mills, 858 second-feet; for supply of canal, 583 second-feet; total, 3,328 second-feet.

sluiceways. Under the provisions of the laws of 1825, a public auction was held in the village of Lockport, in the fall of that year, and the right to use this surplus water sold to Messrs. Richard Kennedy and James H. Hatch, whose successors at the present day constitute the Lockport Hydraulic Power Company.

Lockport has usually been considered more purely a result of the canal development than any other point in western New York, for the reason that while nearly all other towns in the region had some growth before the Erie Canal was located, it was only in 1821, after the present location for the canal had been definitely decided on, that the nucleus of a village was formed here by the contractors and their workmen employed on the canal. In 1820 there was no frame house or barn within 5 miles of Lockport, and there were less than 600 acres of cleared land in the 4 square miles, of which the city of Lockport is now the center. Moreover, there are no natural advantages which would have naturally led to the growth of an important town at this point. The water supply of the region is so deficient that even to this day the city takes its public supply from Erie Canal, which is grossly polluted with sewage from the city of Buffalo. It may be considered, therefore, that the city of Lockport owes its existence entirely to the creation by Erie Canal of a large water power at this point.

When once started, however, under the impulse of the canal development, Lockport grew rapidly until, in 1829, with a population of 3,000, it was incorporated as a village, and in 1865 as a city. The population in 1890 was 16,038; in 1897 it is estimated at over 17,000.

The total investment in manufacturing plants at Lockport dependent on the Erie Canal water supply amounts to $2,531,000. The total number of establishments is 33, employing 1,880 operatives. The total power now in use on Erie Canal proper is 2,625 net horsepower.

A short distance to the east of the foot of the locks a small stream known as the West Branch of Eighteenmile Creek crosses under the canal. This stream, although having a drainage area of only 1 or 2 square miles to the south of the canal, has cut a deep valley with rapid fall for a considerable distance to the north of the canal. In order to provide for discharging the surplus waters from the canal, an overflow into Eighteenmile Creek was constructed at an early day. A mill was also permitted to take water from the lower level and discharge its tail-water into the creek. Finally the Jackson Lumber Company was permitted to construct a sluiceway on the towpath side, through which it drew for many years about 600 second-feet, and which was all discharged into Eighteenmile Creek. Complaints having frequently been made that boats were drawn against this sluice on the towpath side, the superintendent of public works, in 1892, granted a formal permit to the Jackson Lumber Company to construct a sluice and subway under the canal bottom, by which this water is now drawn from the berme side. Under this permit a substantial masonry sluice was constructed in 1893. In the meantime the Jackson Lumber Company has gone out of existence, and this water power has passed into the hands of the Traders' Paper Company, which now occupies the site with its pulp mill No. 1.

West Branch of Eighteenmile Creek descends about 175 feet within the limits of the city of Lockport, of which 148 feet have been utilized for power during recent years.

The following are the companies now using power on this creek and the horsepower used by each:

Power utilized on West Branch of Eighteenmile Creek.

	Horsepower.
Traders' Paper Company	1,060
Lockport Paper Company	230
Niagara Paper Company	115
Westerman and Company	320
Cascade Pulp Company	925
Cowles Smelting Company	1,185
Total	3,835

The output of the establishments on West Branch of Eighteenmile Creek is about $2,000,000 a year; but this sum includes the output of the Indurated Fibre Company, which, while operating by steam power, depends largely for a supply of pulp on the Cascade Pulp Company. In any case, the figures show the magnitude of the manufacturing interests which have been fostered in the valley of West Branch of Eighteenmile Creek, by discharging into that stream about 300 second-feet of water from the Erie Canal.

With 2,625 net horsepower in use on the canal proper, and 3,835 on West Branch of Eighteenmile Creek, the total actually in use at Lockport, and dependent on Erie Canal for its water supply, is 6,460 net horsepower.

No statements as to the value of the annual product of the manufacturing establishments on the raceways of the Lockport Hydraulic Power Company have been given. It is therefore impossible to state accurately the value of the total annual product at Lockport. As several of the establishments there are very extensive, including the Holly Manufacturing Company, it may be assumed that the annual output of this portion of the Lockport manufactories has a value, at least, of $1,000,000; hence we reach a total value of the annual product for the whole city of about $3,000,000.

The annual rental paid to the State, under the terms of the original lease, is only $200. At first sight it appears that there is here a most marked case of what could only be termed blundering on the part of State officials, although on analyzing the matter it is found that this extreme view is hardly correct. In the first place it must be remembered that this lease was granted not only by authority of an act of legislature, but was only granted after a public auction had been held, at which Messrs. Kennedy and Hatch were the highest bidders. As already shown, had not the special conditions created by Erie Canal existed at Lockport, there would, in all probability, have been no thriving city at that point, but the area on which Lockport now stands would have been farming land, with no more value than now attaches to farming lands in the adjoining township of Lockport.

In order to show the results of this lease, at $200 a year, a study has been made of the growth of Lockport from the year 1865, when Lockport became a city, to 1896. It appears, for instance, that the valuation of the city has increased from less than $3,000,000 to over $6,700,000, and that the total State tax collected up to and including the year 1896 has amounted to over half a million dollars. If this had remained as a small farming community the State tax would probably not have been more than 3 per cent of this amount. Using this tax return as a basis, it has been computed that there has been an actual increase of wealth to the people of the State by the existence of Lockport of over one and a half million dollars, not including in this the actual increased value of the city itself. The conclusion is drawn that the benefit to the State at large has been very great on account of this expenditure for internal improvement, irrespective of questions of navigation.

POWER AT MEDINA.

The Oak Orchard feeder and the water power at Medina present somewhat different points for consideration from those at Lockport.

About 1820 the canal commissioners caused a cut-off channel to be constructed through Tonawanda swamp between Tonawanda and Oak Orchard creeks, whereby the early summer flow of Tonawanda Creek is diverted into Oak Orchard Creek. Oak Orchard Creek passes under the Erie Canal at Medina, and the original feeder channel at that place was an artificial channel leading from a dam thrown across the creek and entering the canal near West Branch of Oak Orchard Creek at Medina. At some period subsequent to 1823 a race way was constructed by private parties leading from a second dam higher than the feeder dam and conducting water into the central part of the village, where, after it is used, it is finally allowed to pass into the canal. During the enlargement of 1836 to 1862 the water-surface level of the canal at Medina was raised, and inasmuch as this change necessitated raising the feeder dam somewhat, it was finally concluded to discontinue the feeder and depend entirely on the race way for such supply as the canal might receive at this point.

Oak Orchard feeder has been considered as furnishing about 27 cubic feet of water per second to the canal, although measurements made in 1850 show about 37 cubic feet per second. Since then the clearing up of forests and the drainage of Oak Orchard and Tonawanda swamps have tended to reduce materially the low-water flow until it is probably less than 27 cubic feet per second. Moreover, for the future, the dry-weather yield from this drainage area may be expected to be somewhat less than in the past, because of the deepening of the channel of Oak Orchard Creek and of the crosscut authorized by the laws of 1893. The act provided for deepening the channel of Oak Orchard Creek from a point $2\frac{1}{2}$ miles below where Tonawanda Creek enters the Oak Orchard and for the cleaning, improving, widening, and deepening of the channel of East Branch of Oak Orchard Creek. This work has been done as a sanitary measure, and its effect will probably be to run the water out of the swamps more rapidly in the spring, thus materially decreasing the dry-weather flow.[1]

According to a statement furnished by Mr. A. L. Sweet, president of the Business Men's Association of Medina, the number of operatives employed in 1896 in manufacturing enterprises dependent on water power at Medina was 515; the amount of capital invested in establishments actually in operation was $371,000, while the value of the annual product of the same establishments was $575,000. These figures do not include the Medina Falls flouring mill, which was idle at the time these statements were made.

The total developed water power at Medina, on the race way and on the Oak Orchard Creek, is estimated at 827 horsepower, which includes the wheels at Medina Falls flouring mill. Deducting these wheels, amounting to 338 horsepower, the total actually in use in 1896 is 489 horsepower. The use of water at the establishments on the creek varies from 110 cubic feet per second to 49 cubic feet per second, the former quantity being due to the Medina Falls flouring mill, where the head is 33 feet. Relative to the fine power at Medina Falls, it may be stated that it is improbable, considering the amount of power available at this location, that it will remain unutilized for any great length of time. The trouble at Medina Falls flouring mill is the same as that affecting the large flour mills at Black Rock and other places in New York—the competition of cheap grain and transportation from Western mills.

Without going into the historical part of the subject, it may be said that the mill owners at Medina claim that by reason of the granting of a right of way for the cut-off between Tonawanda and Oak Orchard creeks, and the gift of 100,000 acres of land to the canal fund by their original grantor, the Holland Land Company—a part of the consideration for which was an improvement of the water power of Oak Orchard Creek—they have an equitable right to the use of the water of the feeder. If, therefore, the effect of the drainage authorized by the laws of 1893 has been to decrease the low-water flow of

[1] For extended account of Oak Orchard Creek and its relations to the feeder, see Report on the drainage of the Oak Orchard and vicinity streams, in the Fourth Ann. Rept. of the State Board of Health (1883), pp. 43-116.

Oak Orchard Creek, it is maintained that the mill owners are entitled to enough water from the canal to make good the deficiency.

There are a number of other points on the Erie Canal where water powers have been fostered under the provisions of the laws of 1825, but lack of space precludes discussion of that phase of the subject.

SELLING PRICE OF WATER POWER.

The principal places in New York State at which hydraulic developments have thus far been made for the purpose of selling power are Oswego, Cohoes, Lockport, and Niagara Falls. At Oswego the power on the east side of the river is owned by the Oswego Canal Company, the development being by a canal 4,000 feet long, with an average surface width of 60 feet and a depth of 6 feet. The water from this canal is dropped into Oswego River at the level of Lake Ontario. The working head is from 18 to 20 feet, although with high water in the canal and low water in Lake Ontario, the working head becomes somewhat greater.

The State controls the first right to the flow of Oswego River in order to maintain slack-water navigation in the pool above the dam at the head of the Oswego Canal Company's race way, all water not needed for canal purposes being equally divided between the Oswego Canal Company's race on the east side and the Varick Canal on the west side. The Oswego Canal Company gives a 999-year lease of water, but without land for location of buildings. A water right on this canal is called a run, meaning, probably, the amount of water required to drive a run of stone, a run of water being taken at 11.75 second-feet which, under the ordinary working head of 20 feet, will, at 75 per cent efficiency, produce 20 horsepower. There are assumed to be 32 first-class runs, the rental for which is $350 a year for each run. At this price the cost of a horsepower a year, with 75 per cent efficiency, becomes $17.48, or the cost of a gross horsepower a year becomes $13.11. There are also 32 second-class runs, of which the rental varies from $250 to $300 a year for each run. Further, there are surplus runs which are rented at a little over one-half of the rental charged for first-class runs. In case of a shortage of water the surplus runs are shut down successively, beginning with the most recent leases; after this the second-class runs share equally with one another in reduction; and finally, in case of extreme shortage, the first-class runs are similarly cut down.

The Varick Canal on the west side of the river controls one-half of all the water not needed for navigation purposes, the same as the Oswego Canal Company's canal on the east side. In order that the water may be divided equally between these two canals both have the same aggregate waterway at the head gates, and by gages on both sides, which are examined whenever necessary, it can be seen whether one canal is drawn below the other, and the gates changed accordingly. On this canal there are recognized 50 first-class runs, 17 second-class, and an unlimited number of third-class. For first-class runs the rental is from $250 to $300 per annum; for second and third class it ranges from $125 to $150. By a decree of the supreme court, dated August 21, 1875, a run of water on the Varick Canal ranges between 28 cubic feet per second, under a head of 12 feet, and 25 cubic feet per second, under a head of 13 feet. The actual working head is, however, ordinarily only about 10 feet, so that on the foregoing basis a run of water may be taken as 33.3 cubic feet per second. At the price of first-class runs of from $250 to 300, and with 75 per cent efficiency, the cost per horsepower per annum varies from $8.80 to $10.56, a run on the Varick Canal being equal to 33.3 cubic feet per second on 10 feet head, an amount of water which yields 37.9 horsepower under that head.

As to the difference in cost of water on these two canals at Oswego, it may be pointed out that the Oswego Canal Company's race has a substantial advantage over the Varick race, in that it extends to the harbor, enabling vessels to come directly alongside of the mills. Moreover, the division of water rights is such that a first-class run of water can always be depended on along the Oswego Canal Company's race, but can not on Varick Canal.[1]

At Cohoes we have the great power development built up by The Cohoes Company, which has, by careful management of the water power, built up at this place a fine manufacturing city of 25,000 inhabitants. Lack of space will not permit description of this development in detail.

The Cohoes Company not only owns all of the hydraulic canals, but also the land adjoining the canals. It gives to manufacturers a perpetual lease of land and water, the entire property leased remaining subject to a rental of $200 per year per mill power. On this basis the land is regarded as donated and the rental applies only to the water power. Formerly, the standard for measuring water was 100 square inches, to be measured through an aperture in a thin plate 50 inches wide, 2 inches deep, and under a head of 3 feet from the surface of the water to the center of the aperture; but in 1859 a series of measurements were carefully made under the direction of the late James B. Francis, using an old canal lock as a measuring chamber. These measurements showed that the old standard corresponded to about 5.9 cubic feet of water per second. As a result 6.0 cubic feet of water per second, under 20 feet head, was taken as a new standard constituting a mill power. On this basis a mill power is equivalent to 13.63 gross horsepower, which, at $200 per mill power per annum, costs $14.67 per gross horsepower per annum. At 75 per cent efficiency the annual rental for water for net hrrsepower becomes $19.57. In

[1] For additional detail of the water power at Oswego, see Report of Water Power of the United States, Tenth Census, Vol. I, pp. 24-27.

regard to just what is paid for by the annual rental, both at Oswego and Cohoes, it may be remarked that the foregoing prices are for water in the race way, the company maintaining the dams, head works, and main race ways, the lessee taking the water at the face of the race way and maintaining his own head gates, flumes, bulkheads, wheels, and any other appliances necessary for utilizing the water in the production of power.

The water power at Lockport, owned by the Lockport Hydraulic Company, is formed by the drop of the surplus water of the Erie Canal through a distance of 58 feet. A run of water at Lockport does not appear to be very well defined, but the rental charge ranges from $12.50 to $16.67 per effective horsepower. So far as known to the author, just what constitutes an effective horsepower has not been defined.

At Niagara Falls the rental price of undeveloped hydraulic power has been fixed at from $8 to $10 per gross horsepower per annum, the party renting the power taking the water at the face of the head race and making its own connection with the discharge tunnel. Electric power by a two-phase alternating current as it comes from the generator is sold in blocks of 2,000 or 3,000 horsepower, at $20 per net horsepower per annum, the purchasers furnishing transformers, motors, and all other electric appliances. In small blocks the price has been fixed somewhat higher.

A small amount of power has also been sold at different times at Rochester, but since the power at this place is nearly all held by manufacturers who use it at first hand, nothing like a fixed price has been made at Rochester. Generally, power rented has been in small quantities and in connection with floor space, the rental price being really for floor space with small power furnished. Reckoning on this basis, small powers have frequently been rented at Rochester at as high a price as $100 per horsepower per year, this being for power on the shaft, all expenses of maintaining wheels, transmission shafts, etc., being borne by the owner.

The electric companies at Rochester furnish electric power in small blocks at 3 cents per electric horsepower per hour, which, on the basis of ten hours a day and three hundred and ten days a year, becomes $93 per electric horsepower per annum.

STATE OWNERSHIP OF INLAND WATERS.

Without going into a detailed discussion as to State ownership of inland waters in New York, attention may be called to a few of the more essential facts. The absolute ownership by the State of the beds and banks and water flowing in the Hudson and Mohawk rivers has been confirmed by repeated decisions of the highest courts of the State. By reason of the peculiar circumstances of the early settlement of the country the English common-law rule applies to all the streams of the State except the Hudson and Mohawk, from which it results that all other inland streams are owned to the thread of the stream by the abutting proprietors.

Owing to a confusion of ideas—largely on the part of citizens appointed to the position of canal appraisers, where they exercised to some extent judicial functions—there arose in the early days a broad claim of State ownership to inland waters tributary to the Erie canal. The claim was, however, finally decided in the negative. This condition has, in the case of Genesee River, worked great injustice to the riparian owners, in that under a claim of temporary diversion and an assumed right of permanent appropriation by a statutory enactment declaring the stream a public highway no adequate damages have ever been paid for the diversion actually made from the stream for many years.

A similar lack of appreciation of the real relations of the State to individual citizens in regard to common rights in running streams has apparently led to the enunciation of a course of action on the part of canal officials which, to some extent, in effect confiscates private property.

In the case of Black River the State has extensively adopted the method of compensation in kind rather than compensation in money. In view of the large development of storage on Black River, under the provisions of chapter 181 of the laws of 1851, in excess of what is really required there actually to make good the diversion during the low-water season, and, further, by reason of the State's finally placing the management of the principal reservoirs there in the hands of a commission of owners and users of water power, as provided by chapter 168 of the laws of 1894, it may be assumed that as regards Black River, the State has adopted the policy of conservation of water power, such policy being in line with the best thought of the present day.

In the case of Skaneateles Lake there was for several years a struggle between the State and the city of Syracuse as to the right of that city to obtain the municipal water supply from Skaneateles Lake, the extraordinary feature of that controversy being the assumption on the part of the agents of the State that the municipalities of the State, even in the important matter of public water supply, had no rights which the State apparently was bound to respect.

It may be pointed out that the considerable diversity of law and policy, in regard to the rights of riparian owners thus shown to exist in the State of New York, can not operate other than to discourage the full development of the State's natural resources. What is greatly needed, therefore, in the State of New York is a consistent policy of some sort as between the State, the navigation, the manufacturing, and all other interests, in which each shall receive proper consideration. Thus far navigation interests have usually been placed first, although it is clear that had there been a more thorough balance, the State as a whole would have been considerably in advance of its present position.

FUTURE USE OF WATER POWER IN NEW YORK.

In the foregoing pages we have seen that the Erie Canal was a development from the necessities of commerce, not only for the State of New York, but, as a means of connecting the Atlantic Ocean with the waters of the Great Lakes, for accelerating the industrial development of the Northwestern States. However, in the nineteenth century events move rapidly, and what was true of the Erie Canal thirty to fifty years ago is not necessarily true to-day. Railway systems have now developed to such completeness as to compete successfully with water transportation by a channel of the size of the Erie Canal. The Erie Canal, therefore, has no longer an indispensable place in our transportation system. Apparently it should either be radically enlarged, with entirely new methods of management, or else abandoned in favor of a ship canal along other routes.

During the period covered by the rise and decline of the Erie Canal as the important factor in through transportation between the East and a large portion of the West the economic conditions of the interior portion of New York have entirely changed. Cheap transportation, by way of Erie Canal and the Great Lakes, has led to a phenomenal development of agriculture on the broad plains of Minnesota and the Dakotas, where, by the use of modern agricultural machinery, grain can be raised at a profit at such prices as to drive the New York grain grower from the market. The cheap transportation afforded by the Erie Canal has, therefore, to a considerable degree, led to the passing of supremacy from the hands of the Eastern farmer, a loss which can only be regained by the development to the fullest extent of the manufacturing industries of New York, thus making a home market for farm products that can not be transported a long distance, such as garden truck and small fruits. The people of the State of New York can purchase the Western breadstuffs as cheaply as they can be produced at home, and this condition is likely to continue indefinitely.

The long supremacy of the navigation interests has moreover led to the incorporation in the law, jurisprudence, and public policy of this State of certain rules of action as to the right to use the water of inland streams, which have tended to discourage the full development of manufacturing interests which now appears desirable, although the author views with satisfaction the rapid change of public sentiment now taking place on these questions. That manufacturing industries by water power are rapidly increasing in the State is made sufficiently clear by the following statistics:

According to the United States censuses of 1870 and 1880 the total developed water power of the State of New York was, in 1870, 208,256 horsepower; in 1880, 219,348 horsepower; increase in the ten years, 11,092 horsepower. The increase in ten years of 11,092 horsepower is equivalent to an increase of 5.4 per cent. The United States census of 1890 did not include any statistics of water power, and it is impossible therefore to state definitely the horsepower in that year; still, taking into account the great increase shown by the special investigations on Hudson River in 1895, on Genesee River in 1896, and at Niagara Falls in 1897, and also considering the advances in paper making—a water-power industry—as well as the great development now taking place at Massena, the increase for the whole State from 1880 to 1900 may be estimated at about 120 to 140 per cent. On this basis there will probably be in use in New York State at the close of the nineteenth century a total water power of something like 500,000 gross horsepower. The manufacture of mechanical wood pulp alone consumes about 125,000 gross horsepower. These figures, while very suggestive as to the future, are nevertheless rendered more pertinent by considering that with full development of the water-storage possibilities of the State, as well as the possibilities of power development on Niagara and St. Lawrence rivers, we may hope ultimately to reach a water-power development in the State of New York something like the following:

Possible development of water power in New York.

	Gross horsepower.
Streams tributary to Lake Erie	3,000
Niagara River (in New York State)	350,000
Genesee River and tributaries	65,000
Oswego River and tributaries	40,000
Black River and tributaries	120,000
Other tributaries of Lake Ontario	10,000
St. Lawrence River	400,000
Oswegatchie, Grass, Racket, St. Regis, Salmon, Chateaugay, and other streams tributary to the St. Lawrence	150,000
Saranac, Ausable, Lake George Outlet, and other streams tributary to Lake Champlain	40,000
Hudson River and tributaries, not including Mohawk River	210,000
Mohawk River and tributaries	60,000
Streams tributary to Allegheny River	5,000
Streams tributary to Susquehanna River	25,000
Streams tributary to Delaware River	30,000
Water power of Erie Canal	10,000
Total	1,518,000

But 1,518,000 gross horsepower has an effective productive value in manufacturing of say $100 per horsepower per annum, or the inland waters of this State have an ultimate economic value, when fully developed, of at least $151,800,000 per annum. They may therefore be considered, in producing capacity, substantially equal to the entire agricultural product of the State in 1890, which, according to the United States census of that year, amounted to a total of $161,593,009.

Indeed, taking into account that agricultural values are continually depreciating, and water-power values appreciating, it is probable that ultimately, if New York State agriculture remains on the same basis as at present, the water-power values will considerably exceed the agricultural values. It is probable, however, if the manufacturing industries of this State are ever so far developed as to bring water power into use to the extent of 1,518,000 gross horsepower, that the local demand for agricultural products will have considerably changed the present downward tendency. As an off-hand figure, we may, therefore, place these two values, at some not very distant date, as equal, and aproximating about $200,000,000 per annum.

OBSTRUCTIVE EFFECT OF FRAZIL OR ANCHOR ICE.

A very serious difficulty in operating water powers on many of the more rapid streams of this State is that caused by the formation and agglomeration of frazil and anchor ice, and probably there is no subject in connection with water-power development which presents so many difficulties as this. So far as can be learned, nothing has been done in the State in the way of studying these phenomena, although the water powers on many New York streams are reported as subject to interruption nearly every year on account of the formation of frazil and anchor ice. The way to find a remedy is first to ascertain all that can be learned in regard to the difficulty to be overcome. From this point of view it is deemed proper to include herein a short account of studies of frazil and anchor ice made in the neighboring Dominion of Canada.

Under the direction of John Kennedy, chief engineer of the harbor commissioner's works at Montreal, very extensive studies of the formation of frazil and anchor ice have been made. The terms "frazil" and "anchor ice" have been used synonymously, and are apparently often understood as the French and English words for the same thing, but the following from the Report of the Montreal Flood Commission of 1890 will serve to define the difference. According to this report, frazil is formed over the whole unfrozen surface wherever there is sufficient current or wind agitation to prevent the formation of border ice; whereas the term anchor ice includes only such ice as is found attached to the bottom. Frazil is frequently misused by being made to include ice formed on the bottom, as well as throughout the mass and on the surface of a river, although properly it should be only applied to floating ice. The common theory has been that anchor ice first forms on the bottom, subsequently rising. The Montreal studies, however, show that this is hardly true. At times the whole mass of water from surface to bottom is filled with fine needles which actually form throughout the water mass itself.

As to the remedy, the studies are hardly complete enough to indicate the best course to pursue. As practical hints, it may be stated that in locating dams on streams specially subject to this difficulty they should be placed with reference to as long a stretch of backwater and as great depth as possible, all the studies thus far made tending to show that the formation is most extensive in shallow, rapid-flowing water. Usually trouble from frazil and anchor ice extends through a period of a day or two; and at very important plants, where even a short interruption would be a serious matter, arrangements may be made for using steam at the head works for keeping the racks open. This plan has been successfully pursued at the waterworks intakes of several of the Great Lake cities. In the case of power plants, where much larger quantities of water are required and the stream flows with greater velocity, the amount of steam required may be found to be very large.[1]

WATER YIELD OF THE SAND AREAS OF LONG ISLAND.

Long Island is about 114 miles in length, with a varying width of from 10 to 20 miles. Its watershed line consists of a regular ridge of low hills running from New York Bay to the eastern extremity of the island. The highest points of this ridge are about 350 to 390 feet above sea level. This ridge, which is believed to be a part of the terminal moraine of the great glacier, consists mainly of compact drift and bowlders, running at times into clay and coarse gravel. The considerable number of small ponds along the ridge evidence the compactness of its surface material. The slopes and spurs of the central ridge run into Long Island Sound on the north, making an irregular shore line, broken into bays and low headlands. On the south side the slopes lose themselves in a grassy plain sloping gently toward the coast. In its widest part it is called the Hempstead Plains, and stretches for a distance of from 5 to 15 miles between the foot of the central ridge and the Atlantic shore, which is very regular in its outer beach line; but an inner and more irregular beach exists, formed by the shallow waters of Jamaica and Hempstead bays. The Atlantic shore does not anywhere touch the slope of the central ridge, but is separated from it by the wide gravelly plain just referred to.

Numerous small brooks originating on the south slopes of the central ridge cross the gravelly plain, delivering their waters to the Atlantic. On the largest of these brooks gristmills were established at an early date, with ponds of from 8 to 40 acres of water surface and from 5 to 9 feet depth of water.

The fall at these dams rarely exceeds 8 feet. The original municipal water supply of the city of Brooklyn, as constructed about 1856 to 1859, had its source in the Hempstead Plains, several of the large brooks flowing from the central ridge to the Atlantic being appropri-

[1] For reference to the literature of frazil and anchor ice see (1) Report of the Montreal Flood Commissioners of 1886; (2) Reports of the Harbor Commissioners of Montreal for the years 1885, 1887, and 1895; (3) Paper on Frazil ice and its nature, and the prevention of its actions in causing floods, by George H. Henshaw, Trans. Can. Soc. C. E., Vol. I, Part I, pp. 1-23; and (4) Paper on the Formation and agglomeration of frazil and anchor ice, by Howard T. Barnes, in Canadian Engineer, Vol. V (May, 1897).

ated for this purpose. A distributing reservoir was established on the central ridge at an elevation of 170 feet above tide, with the water of the brooks forced thereto by pumping. These brooks were all mainly fed by springs delivering directly into their ponds and channels. The length of these water courses from where the water was taken to the summer sources rarely exceeds 4 miles. In the original construction the waters of these ponds were conveyed by small branch conduits to a large main conduit extending from the most easterly pond or reservoir to the pump well at the engine house, which was located at the foot of the ridge on which the Ridgewood distributing reservoir was situated, not far from the east line of the city of Brooklyn. The main conduit was so located that the water flowed to the engine house by gravity. The following are the statistics of the six ponds originally taken for the Brooklyn city supply, the minimum deliveries here given being as ascertained by measurements during the months of September and October, 1856 and 1857. The figures represent the natural delivery of each stream at its lowest stage of water, and do not include any encroachment upon the stored water which each pond retained, when full.

Area of surface, minimum flow, and elevation of overflow of six ponds originally taken for the Brooklyn city supply.

Pond.	Area of surface (acres).	Minimum flow (cubic feet in 24 hours).	Elevation of overflow above tide (feet).
Jamaica	40.00	419,315	7.90
Brookfield	8.75	265,098	15.40
Clear Stream	1.07	100,448	11.50
Valley Stream	17.78	325,291	12.80
Rockville	8.00	353,388	12.60
Hempstead	23.52	1,054,713	10.60

The same streams were measured in October and November, 1851, and the aggregate result then was 3,137,500 cubic feet. With the exception of Clear Stream, they were again measured in October, 1852, the result then being 2,606,300 cubic feet in 24 hours.

According to a survey made by Theodore Weston in the fall and winter of 1859, the drainage area of the streams originally taken for the municipal supply of Brooklyn was found to measure 46.8 square miles, but subsequent measurements have placed it at 49.9, which is the figure now used.[1]

As already stated, the drainage grounds lie mainly on the Hempstead Plains, although a small portion may be considered as lying on the southern slope of the central ridge. The ridge slopes are composed of clay and alluvial earth, with little power of retaining

[1] As to the difficulty of determining just what the drainage area of any one of these streams actually is, see I. M. De Varona's History and Description of the Brooklyn Waterworks, 1896.

water. Hempstead Plain, on the other hand, consists of a very uniform deposit of sand and gravel with occasional thin veins of clay; hence Hempstead Plain is largely receptive and retentive of water. The sand and gravel on this plain serves two purposes as regards the rainfall sinking into it: (1) It retains the water, only gradually delivering it to the surface in the valleys of the brooks or on or near the seashore in the form of springs; (2) it filters and purifies it, the gravel and sand performing the function of a natural filter bed. It is considered that but a small portion of the ground water of this gravel plain has been derived from the rainfall of any single year. The greater portion of it is considered to have collected during a series of years. Borings and open wells show that this ground water has a nearly uniform inclination toward the south shore of about 12 feet per mile.

Upon the low ridges lying between the several streams crossing Hempstead Plain the inclination of the ground water varies with the width of the ridge, and is steeper in these parts than on the main slope toward the sea, the resistance of the retaining material there being proportionately less. So long as the slope of the ground water is left undisturbed by pumping, as from a series of wells, the permanent slope of the ground water is determined by the resistance of the material through which it flows. As regards the minimum flow of the streams receiving these underground waters, the longer the time occupied by that portion of the rainfall which sinks into the ground in reaching the outlets the greater will be the minimum flow of the stream as compared with its total flow; on the other hand, the shorter the time the smaller the minimum flow. In the case of the Long Island streams the minimum flows are not very large, a fact which indicates that the permanent regimen of these streams is probably maintained by the accession of the absorbed rainfalls of several years. It follows that so long as the basins are not drawn upon very greatly in excess of their flowage capacity the permanency of Long Island ground water supplies is only moderately affected by variations in the yearly rainfall.[1]

The water supply of the city of Brooklyn has frequently been increased in order to meet the necessities of the constantly increasing population. Additional drainage areas have been taken, and open wells and driven-well systems have been constructed and additional streams and ponds appropriated. At present there are a number of deep open wells, each about 50 feet in diameter, and several driven-well stations. For details of the original conduits, ponds, and streams reference may be made to a description of the Brooklyn waterworks in Water Power of the United States, Tenth Census, 1880, Volume XVII, as well as to the histories of the Brooklyn waterworks.

[1] The foregoing statements relating to the water-yielding properties of the Long Island sands are mostly derived from Kirkwood's History of the Brooklyn Waterworks and Sewers, published in 1867. For a more recent, as well as more extended, discussion of the same subject see De Varona's History and Description of the Brooklyn Waterworks.

In a report on the future extension of the water supply of Brooklyn, by Mr. I. M. De Varona, engineer of the water supply, transmitted to the common council, January 31, 1896, tables are given of the total monthly and average daily quantities of water pumped into the Ridgewood reservoir for the years 1860 to 1895, inclusive.

The accompanying table has been condensed from this report, giving in calendar years the total rainfall upon the watershed and the per cent of this utilized by pumping at Ridgewood. The average yield utilized is also expressed in cubic feet per second per square mile of watershed. This was originally 49.9 square miles, but was increased in 1872, being in subsequent years 52.3 square miles until 1883, when it was increased to 64.6 square miles, and in 1885 to 65.4 square miles. Considerable additions were made in 1891, and from that time on the area is given as 154.1 square miles. In 1860 the rainfall was 37.65 inches, and the total amount of water pumped was equivalent to a depth of 1.44 inches on the watershed, or 3.82 per cent of the total rainfall. In 1896 the total rainfall was 38.82 inches. The amount of water pumped during that year would cover the watershed to a depth of 11 inches, this being over 28 per cent of the total rainfall. The average yield as obtained by pumping was 0.81 cubic foot per second per square mile of watershed.

Total annual rainfall, per cent utilized, and average yield per square mile of watershed of Brooklyn waterworks.

Year.	Rainfall in inches.	Per cent utilized.	Second-feet per square mile.	Year.	Rainfall in inches.	Per cent utilized.	Second-feet per square mile.
1860	37.65	3.82	0.11	1879	39.61	33.40	0.97
1861	45.65	3.92	0.13	1880	40.76	30.23	0.90
1862	38.02	5.73	0.16	1881	39.53	29.42	0.86
1863	32.76	8.39	0.20	1882	39.83	30.73	0.90
1864	32.00	10.53	0.25	1883	37.22	33.05	0.91
1865	46.14	8.39	0.28	1884	45.39	27.89	0.93
1866	51.68	8.88	0.34	1885	36.85	37.94	1.03
1867	54.61	9.39	0.38	1886	51.38	28.32	1.07
1868	38.58	17.29	0.49	1887	45.66	32.59	1.10
1869	43.13	17.20	0.55	1888	48.45	33.19	1.18
1870	39.25	19.82	0.57	1889	56.54	29.54	1.23
1871	51.26	15.78	0.60	1890	52.15	33.90	1.30
1872	39.75	23.47	0.67	1891	39.18	44.82	1.29
1873	47.99	20.88	0.74	1892	37.75	24.53	0.68
1874	45.83	21.49	0.73	1893	39.62	26.27	0.77
1875	40.90	26.89	0.81	1894	36.88	26.33	0.72
1876	41.77	27.08	0.83	1895	35.64	28.98	0.76
1877	40.18	30.29	0.90	1896	38.82	28.31	0.81
1878	48.66	25.15	0.90				

Generally the Brooklyn waterworks have not been so designed as to furnish records of the quantity drawn from these several different sources. There are also no records of the heights of the ground water at different points in the drainage area. If such were to be kept for a series of years, the records of the Brooklyn waterworks would possess a value not easily estimated. They would give a far more positive indication of the amount of water that can be drawn from such sandy areas than can now be gained from them. A few tests, however, of some of the driven-well plants have been made in the last few years.

At a test of the old driven-well plant at Spring Creek, made from October 22 to November 20, 1894, water was pumped at an average rate of 4,091,551 gallons in 24 hours. The elevation of the underside of the discharge valve of the pump was 12.3 feet above datum. On October 22, at the beginning of the tests, the average elevation of the water in the wells was 4 feet below datum. The quantity pumped in 24 hours, on October 22, was 4,488,275 gallons. On November 20, the date of the conclusion of the test, the elevation of water in wells was 7.7 feet below datum, and the quantity pumped on that day in 24 hours was 4,112,663 gallons. The total quantity pumped during the entire period from October 22 to November 20 was 122,746,525 gallons. The taking of this quantity of water from the wells resulted, therefore, in lowering the ground water a total of 3.7 feet.

A new driven-well plant at Watts Pond was subjected to a test of capacity extending continuously from January 3 to February 2, inclusive. In 1895 a rather extended series of tests were made of a number of the wells of the Brooklyn water supply in order to determine the yield as well as the extent of the underground supply. The following particulars of these tests have been derived from Mr. De Varona's report, as contained in the annual report of the commissioner of city works for the year 1895.[1]

The flowing wells at Jameco were tested from January 3 to 14, inclusive. During this period the wells were operated singly and in groups of 2, 3, and 4, in all possible combinations, and observations were taken to determine the elevation of the ground water. Upon completion of the tests a series of observations was taken, extending to January 30, to determine the normal water level. The results of these observations may be found in detail in De Varona's report. It was shown that the average yield from one well alone was only 1,000,000 gallons daily, decreasing pro rata up to a total yield of 3,500,000 gallons daily when four wells were in operation. The lowering of the ground water was approximately 5 feet when pumping 1,000,000 gallons, increasing up to approximately 10 feet when pumping at the full capacity developed of 3,500,000 gallons. In this connection it is stated that the water in these test wells is found to rise

[1] For a full account of the Brooklyn waterworks well systems see De Varona's History, etc.

and fall directly with the tide, thus rendering it difficult to state with accuracy the full effect of the pumping on the lowering of the water. To determine this point fully, De Varona states, would require a more prolonged series of observations than it was possible to make in 1895.

Another test was made at Jameco from December 9 to 20, 1895, inclusive. Between this date and the end of the previous tests an additional well had been sunk at Jameco to the depth of 160 feet. The average daily yield shown during the second test was, approximately, 1,000,000 gallons for a single well, with a proportionate increase for each well connected, the yield for five wells being, approximately, 5,000,000 gallons in 24 hours. The lowering of the water during those tests amounted to slightly over 14 feet at Jameco while pumping the 5,000,000 gallons daily from the five wells. The total amount of water pumped during the test was 61,239,555 gallons. The greatest lowering of the underground water level occurred at test well No. 8, where it amounted to 15.23 feet. At that time, when the water at Jameco was at its lowest level, the fall between test well No. 8 and test well No. 11 was 9.9 feet. The normal water level was not restored until twelve days after the tests had ceased.

The results obtained early in 1895 from the test made at Jameco of supplies from deep wells seemed to warrant further investigations as to the possibility of water from deep wells, and the report states that they have been carried on during the year. A series of test wells were driven, extending from the foot of the hill at Ridgewood reservoir to Forest Stream pumping station, each well being carried to a depth sufficient to determine the possibility of obtaining a deep supply from that point. The number of those wells sunk during that year was twelve, and the records of the strata passed through are given in Bulletin No. 138, referred to in the footnote.[1]

Returning to the table on page 194, it may be stated that the tributary drainage area in 1875, the first year for which statistics are given in the table, was 52.3 square miles. The drainage area remained at this figure until January, 1881, in which month, by the bringing of the Springfield pumping station into use, it was increased to 59.4 square miles. In the water year of 1875, with a total rainfall of 41.6 inches, the water utilized amounted to 10.78 inches, or to an average of 513,165 gallons per square mile per day, or to 0.79 of a cubic foot per square mile per second. In the water year of 1880, with a total rainfall of 40.04 inches, the water utilized amounted to 12.37 inches on the watershed, or to 587,568 gallons per square mile per day, or to 0.91 of a cubic foot per square mile per second. In 1881, with a rainfall of 41.52 inches, the total utilization of water amounted to 11.64 inches on the watershed, or to 554,473 gallons per square mile per day, or to 0.86 of a cubic foot per square mile per second. This drop in

[1] For the particulars of the geology of several of the Brooklyn waterworks wells, of which tests were made in 1895, see Artesian-well prospects in the Atlantic coastal plain region, by N. H. Darton: Bull. U. S. Geol. Survey No. 138, 1896, pp. 23-37.

the unit of utilization merely shows the effect of the increase in the area of the watershed.

The tributary watershed remained at 59.4 square miles until August, 1883, in which month the Spring Creek and Baisley's driven-well stations were started. From this date the tributary drainage area is taken at 64.6 square miles. Spring Creek and Baisley's stations marked the beginning of the Brooklyn driven-well system. In the water year of 1884, with a total rainfall of 43.44 inches, the utilization was 12.53 inches, amounting to 594,992 gallons per square mile per day, or to 0.92 of a cubic foot per square mile per second.

In May, 1885, the Forest Stream and Clear Stream driven-well stations were started, thereby increasing the tributary drainage area to 65.4 square miles. In the water year of 1886, with a total rainfall of 50.43 inches, the water utilized amounted to 14.40 inches, equivalent to 685,521 gallons per square mile per day, or to 1.06 cubic feet per square mile per second.

The drainage area remained 65.4 square miles until June, 1890, when it was increased to 65.6 square miles by the addition of the Jameco Park driven-well station. In the water year 1891, with a total rainfall of 40.34 inches, the water utilized amounted to 18.48 inches on the watershed, equivalent to 879,811 gallons per square mile per day, or to 1.35 cubic feet per square mile per second.

Large extensions of the works were made in 1890 and 1891, so that with the beginning of pumping at Millburn on December 17, 1891, the tributary drainage area may be considered as increased from 65.6 to 154.1 square miles, an increase of 88.5 square miles. In the calendar year 1892, with a rainfall of 37.75 inches, the water drawn from the original watershed of 65.6 square miles amounted to 16.81 inches on the watershed, equivalent to 800,191 gallons per square mile, or to 1.24 cubic feet per second per square mile. The water drawn from the new watershed of 88.5 square miles that year amounted to 3.67 inches on the watershed, equivalent to 174,776 gallons per square mile per day, or to 0.27 of a cubic foot per square mile per second. In 1895, with a total rainfall of 35.64 inches, the original watershed of 65.6 square miles yielded 12.62 inches on the watershed, equivalent to 600,723 gallons per square mile per day, or to 0.93 of a cubic foot per square mile per second. The new watershed of 88.5 square miles furnished in that year 8.64 inches on the watershed, equivalent to 411,558 gallons per square mile per day, or to 0.64 of a cubic foot per square mile per second.

Summarizing the information in regard to the water yield of the sand plains of Long Island, it may be stated that the available data indicate a large yield. The streams of eastern New York can not be relied upon in their natural condition to yield more than about 0.3 of a cubic foot per square mile per second, while with an ordinary development of storage the limit may be usually placed at from 0.7

to 0.8 of a cubic foot per square mile per second, or at any rate at not much exceeding 1 foot per square mile per second. The sand deposits of Long Island may, therefore, be considered as great natural reservoirs from which, with proper development, large water supplies may be drawn, the same as from reservoirs artificially created on the earth's surface, these natural underground reservoirs possessing the advantage of furnishing a filtered water of high purity.

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1895.

Sixteenth Annual Report of the United States Geological Survey, 1894–95, Part II, Papers of an economic character, 1895; octavo, 598 pp.

Contains a paper on the public lands and their water supply, by F. H. Newell, illustrated by a large map showing the relative extent and location of the vacant public lands; also a report on the water resources of a portion of the Great Plains, by Robert Hay.

A geological reconnoissance of northwestern Wyoming, by George H. Eldridge, 1894; octavo, 72 pp. Bulletin No. 119 of the United States Geological Survey; price, 10 cents.

Contains a description of the geologic structure of portions of the Bighorn Range and Bighorn Basin, especially with reference to the coal fields, and remarks upon the water supply and agricultural possibilities.

Report of progress of the division of hydrography for the calendar years 1893 and 1894, by F. H. Newell, 1895; octavo, 176 pp. Bulletin No. 131 of the United States Geological Survey; price, 15 cents.

Contains results of stream measurements at various points, mainly within the arid region, and records of wells in a number of counties in western Nebraska, western Kansas, and eastern Colorado.

1896.

Seventeenth Annual Report of the United States Geological Survey, 1895–96, Part II, Economic geology and hydrography, 1896; octavo, 864 pp.

Contains papers on "The underground water of the Arkansas Valley in eastern Colorado," by G. K. Gilbert; "The water resources of Illinois," by Frank Leverett; and "Preliminary report on the artesian areas of a portion of the Dakotas," by N. H. Darton.

Artesian-well prospects in the Atlantic Coastal Plain region, by N. H. Darton, 1896; octavo, 230 pp., 19 plates. Bulletin No. 138 of the United States Geological Survey; price, 20 cents.

Gives a description of the geologic conditions of the coastal region from Long Island, N. Y., to Georgia, and contains data relating to many of the deep wells.

Report of progress of the division of hydrography for the calendar year 1895, by F. H. Newell, hydrographer in charge, 1896; octavo, 356 pp. Bulletin No. 140 of the United States Geological Survey; price, 25 cents.

Contains a description of the instruments and methods employed in measuring streams and the results of hydrographic investigations in various parts of the United States.

1897.

Eighteenth Annual Report of the United States Geological Survey, 1896–97, Part IV, Hydrography, 1897; octavo, 756 pp.

Contains a "Report of progress of stream measurements for the year 1896," by Arthur P. Davis; "The water resources of Indiana and Ohio," by Frank Leverett; "New developments in well boring and irrigation in South Dakota," by N. H. Darton; and "Reservoirs for irrigation," by J. D. Schuyler.

1898.

Nineteenth Annual Report of the United States Geological Survey, 1897–98, Part IV, Hydrography, 1899; octavo, 814 pp.

Contains a "Report of progress of stream measurements for the calendar year 1897," by F. H. Newell and others; "The rock waters of Ohio," by Edward Orton; and "Preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian," by N. H. Darton.

Water-Supply and Irrigation Papers, 1896–1899.

This series of papers is designed to present in pamphlet form the results of stream measurements and of special investigations. A list of these, with other information, is given on the outside (or fourth) page of this cover.

Survey bulletins can be obtained only by prepayment of cost, as noted above. Postage stamps, checks, and drafts can not be accepted. Money should be transmitted by postal money order or express order, made payable to the Director of the United States Geological Survey. Correspondence relating to the publications of the Survey should be addressed to **The Director, United States Geological Survey, Washington, D. C.**

WATER-SUPPLY AND IRRIGATION PAPERS.

1. Pumping water for irrigation, by Herbert M. Wilson, 1896.
2. Irrigation near Phœnix, Arizona, by Arthur P. Davis, 1897.
3. Sewage irrigation, by George W. Rafter, 1897.
4. A reconnoissance in southeastern Washington, by Israel C. Russell, 1897.
5. Irrigation practice on the Great Plains, by E. B. Cowgill, 1897.
6. Underground waters of southwestern Kansas. by Erasmus Haworth, 1897.
7. Seepage waters of northern Utah, by Samuel Fortier, 1897.
8. Windmills for irrigation, by E. C. Murphy, 1897.
9. Irrigation near Greeley, Colorado, by David Boyd, 1897.
10. Irrigation in Mesilla Valley, New Mexico, by F. C. Barker, 1898.
11. River heights for 1896, by Arthur P. Davis, 1897.
12. Water resources of southeastern Nebraska, by Nelson Horatio Darton, 189
13. Irrigation systems in Texas, by William Ferguson Hutson, 1898.
14. New tests of pumps and water lifts used in irrigation, by O. P. Hood, 1898.
15. Operations at river stations, 1897, Part I, 1898.
16. Operations at river stations, 1897, Part II, 1898.
17. Irrigation near Bakersfield, California, by C. E. Grunsky, 1898.
18. Irrigation near Fresno, California, by C. E. Grunsky, 1898.
19. Irrigation near Merced, California, by C. E. Grunsky, 1899.
20. Experiments with windmills, by Thomas O. Perry, 1899.
21. Wells of northern Indiana, by Frank Leverett, 1899.
22. Sewage irrigation, Part II, by George W. Rafter, 1899.
23. Water-right problems in the Bighorn Mountains, by Elwood Mead, 1899.
24. Water resources of the State of New York, Part I, by George W. Rafter, 189
25. Water resources of the State of New York, Part II, by George W. Rafter, 189

In addition to the above, there are in various stages of preparation other pape relating to the measurement of streams, the storage of water, the amount availab from underground sources, the efficiency of windmills, the cost of pumping, an other details relating to the methods of utilizing the water resources of the cou try. Provision has been made for printing these by the following clause in t sundry civil act making appropriations for the year 1896–97:

Provided, That hereafter the reports of the Geological Survey in relation to t gauging of streams and to the methods of utilizing the water resources may b printed in octavo form, not to exceed 100 pages in length and 5,000 copies in num ber; 1,000 copies of which shall be for the official use of the Geological Surve 1,500 copies shall be delivered to the Senate, and 2,500 copies shall be delivered t the House of Representatives, for distribution. [Approved June 11, 1896; Stat. L vol. 29, p. 453.]

The maximum number of copies available for the use of the Geological Surve is 1,000. This number falls far short of the demand, so that it is impossible t meets all requests. Attempts are made to send these pamphlets to persons wh have rendered assistance in their preparation through replies to schedules c donation of data. Requests specifying a certain paper and stating a reason fo asking for it are attended to whenever practicable, but it is impossible to compl with general requests, such as to have all of the series sent indiscriminately.

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