A REPORT

OF A

PLAN FOR SUPPLEMENTING

THE

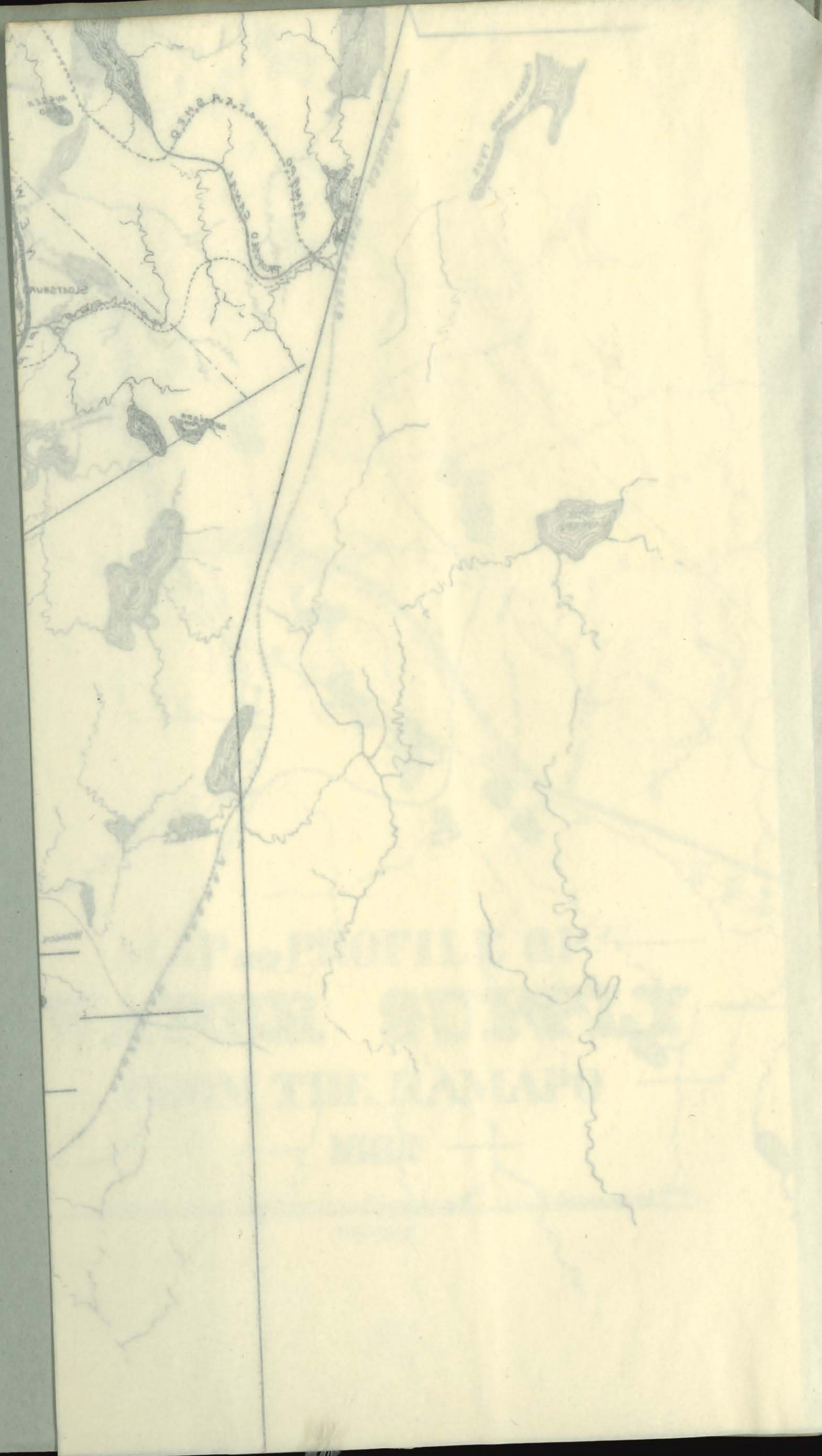
CROTON WATER SUPPLY

TO THE

CITY OF NEW YORK

FROM THE

RAMAPO DISTRICT.



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NEW YORK:
MARTIN B. BROWN, PRINTER AND STATIONER,
NOS. 49 AND 51 PARK PLACE.

1882.

New York, April 30, 1882.

Mr. William J. McAlpine, Civil Engineer:

Dear Sir—Referring to my letter of the 20th January, 1881, and your Report in reply thereto, and to the various verbal suggestions which I have heretofore made to you, I have now to request that you will make all of the necessary instrumental and other examinations in regard to the plan of introducing a water supply to the City of New York, adjunct to the present Croton system, from the Ramapo District, within the State of New York, having in view the following leading objects:

1st. An average daily supply of fifty millions of gallons, and an augmented supply up to the whole available capacity of the Ramapo District, and also a still further supply from the districts adjacent thereto, which can at moderate expense be diverted into the Ramapo system.

2d. That the said waters shall be delivered at the north line of the city at an elevation of about three hundred feet above tide.

3d. That this water may be distributed, if desired, in an independent system of pipes through certain streets of the city, so as to apply its high head to the extinguishment of conflagrations without the intervention of fire engines, and also that it may be used for domestic and other purposes on the elevated annexed district north of the Harlem river, to the Fort Washington and to other high districts of the city.

4th. For the supply of the first fifty millions of gallons I have to request you to avail of the several tributaries of the Ramapo and of the large natural lakes thereon: viz.:

The Stony Brook, Carr Pond and Otter Creek, on the east side of the Ramapo; and the Truxcedo, Sterling, Mount Basha and Monroe Lakes, on the west side.

5th. It is considered advisable to convey these waters in pipes, generally along the Erie railway to the summit between the Ramapo and Hudson rivers, and thence to and across the Hudson, and in the valley of the Saw Mill River, in Westchester County, to the north line of the city.

You are requested to report on the quantity and quality of the water from the Ramapo District, and the cost of the necessary works to introduce this water into New York, and the method of using it for the purposes recited in the third (above-mentioned) suggestion.

Respectfully,

DANIEL JACKSON.

NEW YORK, October 15, 1882.

DANIEL JACKSON, Esq.:

DEAR SIR—In compliance with the requests contained in your letter hereto prefixed, I have to state that the surveys and examinations of the scheme for obtaining a supply of water from the Ramapo District, for the City of New York, adjunct to the Croton system, have been completed, and the results thereof are embraced in the following report, maps, plans and estimates.

Respectfully,

WM. J. McALPINE.

REPORT.

The Croton Aqueduct is now taxed to its utmost capacity, and the supply of water therefrom is conceded to be insufficient for the present requirements.

The demand for water to the Metropolis will increase from year to year, and can only be met, under the present system, by an additional large aqueduct and largely increased storages for water, both of which will be very costly and require many years before they can be rendered available to meet the current demands.

A supply of fifty millions of gallons a day from the Ramapo, of unusually pure and wholesome water, can be delivered at the city at an elevation of three hundred feet above tide level *in two working seasons*, at less cost than from any other source.

An extension of these works can be made at a comparatively moderate outlay, which will add a hundred millions of gallons a day to the first fifty millions.

This immense supply from independent works will always be available, if any temporary disaster should occur to any part of the Croton system.

The Ramapo may be used as an adjunct to the Croton system, and its supply being from independent sources and works, will not be liable to be affected in quantity or quality at the same time or in the same manner.

The water from the Ramapo will be delivered at an elevation sufficient to supply all of the elevated portions of the city by gravity, and thus save the present cost of pumping thereto.

And by means of an independent set of fire water-mains, its whole supply, or any required part thereof, can be delivered throughout the city with such great head as will overtop the highest buildings and do away with the present cost of maintaining the steam fire engines.

The Ramapo water, with a single main line of pipes through the middle of the city, and cross-pipes each way to the Hudson and East rivers, can be delivered into the present street pipes at any desired place in the city, where the quantity or head is too little, and thus increase both to any desired extent.*

The Ramapo river has a drainage area of one hundred and eight square miles within the State of New York, of which eighty-five square miles is available for a supply of water to the city, starting from an elevation of four hundred and thirty-two feet above the level of tide.†

And this available area of water-gathering grounds can be increased to one hundred square miles, at a moderate expense, by diverting the upper waters of a number of streams, adjacent to the crest of the water-shed of the Ramapo.

These water-sheds somewhat resemble those of the upper Croton, but they are at a greater elevation, have more large lakes, steeper slopes of the ground, a less permeable surface, and are occupied with a very sparse population.

The valleys of all of the tributary streams open fan-like towards the watery winds from the ocean, only forty miles distant, and are enclosed in almost mountain hills, which condense the water from the highly-saturated atmosphere, and cause copious rainfalls, which flow rapidly down the steep, rocky, impermeable hill-slopes, and thus escape much of the usual loss of water by evaporation, before it reaches the brooks. The rain gauges on and near this district, and the observed flow-off of the mountain brooks and the main river, as might be expected from these circumstances, show a larger amount of rainfall and a greater ratio of available water therefrom, than is usually obtained from equal areas of water-shed.

* At each of these connections an equalizing valve must be put in, which will automatically regulate the inflow of the Ramapo water, in such quantity and give such head upon the Croton and the house-service pipes as they can stand.

† One hundred and thirty-two feet of this head is required to overcome the resistance of the water flowing through the conduits to the City line.

THE QUALITY OF THE WATER.

The mountains of this district are granitic, and this rock extends under the valleys of all of the streams, except a small portion of the extreme northern end, where some graywacke and limestone is found.

The alluvium of the valleys and hill slopes has been formed by the decomposition of the granitic rocks, and is quartzose sand, gravel, and stone, with many large and small boulders interspersed, all of which lie in shallow beds over the primitive rocks.

A large proportion of the area is covered with woods which are, generally, small trees and bushes.

There are some grazing farms at the northern end, and a few small cultivated fields in the valleys, but the hillsides are generally wooded, and in a few places are used for grazing.

Mines of magnetic iron are found in places, which furnish ore to three smelting furnaces. There are almost no other manufactories in the district, and none of an objectionable character.

The population of the district has not increased in a century, and probably never will increase beyond its present sparse limits, because the unoccupied lands are unfit for cultivation, and there are no facilities or inducements to establish manufactories.

As before observed, the rain water which falls upon the surface of the mountain slopes has no deep beds of porous soil into which it can penetrate and slowly flow out, but it descends quickly over the surface to the brooks, and in heavy rains, produces torrents which would render mill-dams hazardous, and these torrents are followed by long periods when the brooks are comparatively dry.

From these conditions, water power on these streams is nearly or quite valueless; and, therefore, there is no probability in the future, of the establishment of manufactories and their accompanying populations.

The ocean-derived water falls upon the mountain slopes in an almost perfectly pure condition, and when flowing over their surfaces receives no contamination from decaying vegetation or from the pure quartz soil, so that it must be unusually pure and wholesome.

The highly aerated, bright, sparkling waters from these rapid-foaming mountain brooks are the habitat of the speckled trout, the best analysts of water. These fish are never found in water containing anything deleterious.

The waters of the lakes have gravelly or rocky beds, and are supplied from these mountain brooks, and are equally pure and wholesome.

When heavy rains occur, these mountain torrents are frequently charged with fine sand, held in suspension, but when they descend into the lakes, all of such suspended matter is quickly precipitated in these quiescent receptacles.

The impounded waters of the Croton and that of other large cities, at distant intervals of time, have been contaminated by the sudden production of either marine vegetation or minute animal organisms, or rather by the sudden death and decay of these ephemeral productions.

A long-continued term of a very warm, calm atmosphere, and perhaps some as yet unknown agency of electricity, brings the germs of these organisms into sudden life.

As long as they are in equilibrium, the vegetable growth is consumed by the animalculæ, but when either is in excess, death and decomposition follow, and the water is contaminated.

But this continues for only a few days at a time, and by the natural operation of the conversion of their dead bodies into gas, which is driven off by the winds, the water is soon completely purified.

The water from the Ramapo District will be obtained from eight or more separate sources, which differ from each other in location, elevation, exposure and other circumstances to such a degree that not more than two of them can be affected by the above causes at the same time.

If one or more of these eight sources should at any time be affected, an ample supply of pure water can be obtained from

the others, until this operation of self-purification has been completed.

From the foregoing considerations we may conclude with certainty that the water from the Ramapo District will forever be of the most pure and wholesome character.

The valley of the Croton, on the other hand, is already occupied by a considerable population, and many villages and manufactories; and yet, up to the present time, the water therefrom has been comparatively pure and wholesome, though inferior in quality to that of the Ramapo.

The proximity and ready access of the Croton District to New York and its neighboring cities, will cause a rapid and compact settlement and the establishment of numerous manufactories and their accompanying population along its water-courses and railways, which will eventually contaminate the waters from that region.

The officers of the city have already apprehended this future source of contamination, and are now considering the advisability of sewering the whole valley, which will cost a vast sum.

As before observed, the Ramapo District is in no danger of a future contamination of its waters from this or any other cause, and is now and will remain almost perfect in quality.

THE QUANTITY OF WATER WHICH CAN BE OBTAINED.

The Croton Department has measured the monthly flow-off from about twenty square miles of the upper part of the Croton river, and also the rain which fell, for the years 1865 to 1881, inclusive. The monthly mean ratio and the range of the percentage for each month of the flow-off and rain for nine of these years, are given in the note on pages 11 and 12.

I have made similar measurements over larger and smaller areas of water-shed, embracing great varieties of soil, elevation, exposure, etc., and have examined measurements of this character made by many other observers, from which I have established for my own governance a ratio for each month of the year for a certain description of water-shed, which by proper modifications may be applied to cases of this kind with considerable certitude.

These ratios cannot be applied to any single year with much accuracy. If, however, they are applied to a cycle of years, embracing those of large and the largest rainfalls, and of the small and least rainfalls, which a cycle of about ten years will generally cover, the result may be relied on with considerable certainty.

That is, what has been will probably be repeated, and the available quantity of water from any district, if sufficient storage is provided, will be arrived at by an intelligent and careful person, with accuracy, from a knowledge of what has previously occurred.

The rainfall at West Point on the Hudson, seven miles east of the Ramapo water-shed, for the sixteen years from 1865 to 1881, exceeds that at Boyd's Corners, on the upper Croton, by four per cent. per annum, and that at Greenwood on the Ramapo exceeds that at Boyd's Corners for two of these years by fifteen per cent. per annum.*

The rain gauge at Greenwood has an elevation of a hundred feet less than the one at Boyd's Corners, and is more than five hundred feet lower than the mean elevation of the Ramapo water-shed, which is more than a thousand feet above tide, and therefore the rainfall over the whole area of the Ramapo District must be at least twenty per cent. greater than it is over that portion of the upper drainage of the Croton from which the results of the flow-off, before referred to, were derived.

* The rainfall at Lake Hopatong, on the eastern water-shed of the Delaware river, thirty odd miles southwest of the Ramapo, for the twenty-four years from 1846 to 1869, was nearly ten per cent. less than for the same years at West Point (*i. e.* six per cent. less than at Boyd's Corners).

The high range of country to the south of Hopatong cuts off the vapory winds from the ocean, and lessens the rainfall at that place.

A very imperfect measurement of the rainfall for eight of the fifteen years, from 1835 to 1849, at Goshen, ten miles northwest of the Ramapo water-shed, on the slopes of the Walkill, shows only three-fourths as much rainfall as at West Point.

Here again the high range of hills to the south of Goshen cuts off the ocean winds, and greatly lessens the rainfall at that place.

In the calculations which I have made of the available supply of water from the Ramapo District, I have not included this estimated increased quantity of rain and larger proportion of flow-off due to the Ramapo, because the amount demanded by the present project did not require it.

It is proper, however, to add that, if more water shall hereafter be required, the Ramapo District may be relied upon to furnish from twenty to twenty-five per cent. more of available water for the city than I have herein estimated.

Some of the calculated tables are appended. They show that by the Croton basis an average of a million and a third of gallons a day can be obtained from each square mile of the Ramapo water-shed, if storing reservoirs are constructed to retain the excess of the years of large rainfall for use during those of less rain.

There are twelve natural lakes on the tributaries of the Ramapo, which have an aggregate surface of eighty millions of square feet, and by means of moderately low dams at the outlets of each, will have an available capacity for storing nine thousand millions of gallons of water.

It is proposed to construct nine artificial storing reservoirs which will, in the aggregate, hold seven thousand millions of gallons, making a total storage for sixteen thousand millions of gallons of water.

The natural lakes will be of great advantage and economy to the Ramapo system, because their capacity for storage may be utilized beyond their own drainage areas, by proper management in drawing the daily supply, first from the artificial reservoirs below the lakes, and thus keep them as far as possible in condition to receive the water from excessive or long-continued rains.

NOTE A.—The Croton Department has published the amount of rainfall at Boyd's Corners, for the years 1865 to and including 1873, and the quantity of water which flowed off each month from a district of about twenty square miles, of the upper Croton.

These tables show the following mean and ranges of the percentage of the rain which flowed off during the months of the year:

Month of				
January,	Mean of the nine years,	84½ per cent.	Range,	18 to 126 per cent.
February,	" "	82 "	"	62 to 126 "

Month of						
March,	Mean of	the nine years,	104	per cent.	Range,	22 to 158 per cent.
April,	"	"	98	"	"	66 to 158 "
May,	"	"	60½	"	"	45 to 100 "
June,	"	"	44	"	"	18 to 67 "
July,	"	"	18	"	"	7 to 30 "
August,	"	"	19	"	"	3 to 42 "
September,	"	"	30½	"	"	3 to 92 "
October,	"	"	63	"	"	11 to 366 "
November,	"	"	63	"	"	36 to 110 "
December,	"	"	69	"	"	47 to 95 "
Yearly mean			61.3			

The measurement of the rainfall included the snow which fell upon the ground in each month (*i. e.*, its equivalent in water), but the water from the melting of such snows generally passed off several months later, and then showed in the above tables the frequent anomaly of more water flowing off in certain months than the rainfall of the month.

Whenever rain fell on the last days of any of the months, more or less of it did not reach the flow-off guage until the first days of the following months, and thus affected the ratio of the flow-off of both months.

The low ratios in some of the summer months are due to the thirsty condition of the ground and small rainfalls, and to a trifling extent to the absorption of water by growing vegetation.

The ratios of the flow-off are permanently affected by the length of time that the rain water is exposed to evaporation before it reaches the brooks; that is, by the length and declivity of the land slopes, by the permeability of their soils, and temporarily by the absorbent condition of the earth when the rain falls upon it.

When the rain water reaches the brooks, the surface exposed to evaporation is relatively very small.

On the Ramapo the hill slopes of the valleys are steep, the surfaces are frequently of the naked rock, or when covered with soil, it is usually of porous, sandy gravel which allows the rain water to quickly sink beyond the reach of evaporation.

There are very few swampy places and these are generally protected by bushes, and the porous soil elsewhere admits the rain, which sinks deep and, even in the wet season, leaves the upper part comparatively dry to receive fresh supplies of rain.

Under these circumstances the usual loss by land evaporation is reduced nearly to a minimum, and the ratio of flow-off must be unusually large.

The ratio derived from such tables cannot be applied to a single year, but when applied to a continued series of years of rainfall are useful to determine the amount of the storage which must be provided, and then the available quantity deduced therefrom may be relied upon.

The demand for water in a city varies in the different sea-

sons of the year, and I have arranged the present plans so that the supply shall be one-fifth more than the mean at those seasons of great demand.

Works of this character require frequent examination, and I have therefore arranged them all in duplicate, so that the supply shall continue uninterrupted while these necessary examinations are being made.

The aggregated supply will be derived from eight separated districts, any two of which will at any time, furnish the whole quantity for a limited period, and until the others are in condition to furnish it.

There will be two pipe conduits from the Ramapo to the city line, and where they are carried under the Hudson river there will be four lines, which will be placed a considerable distance apart for greater security.

Large storing reservoirs are proposed to be built on each side of the Hudson, which shall give additional security against any interruption of the supply.

The works herein proposed are all designed to be built in so permanent a manner as to prevent the failure of any part, but the duplications above referred to will give the strongest assurance against interruptions, until the use of the works has practically demonstrated to the public the security and permanence of the whole.

Some of the plans herein presented are novel in this section of the country, but they have been thoroughly tested with success elsewhere.

The necessities of the case require the use of many of the pipes of larger size than can be procured of cast-iron of perfectly reliable make, and I have therefore been led to adopt those of wrought-iron lined with brick, for the conduits.

Wrought-iron pipes are universally used for the conveyance of water on the Pacific slope, and have been used in Europe, where they have given complete satisfaction. When properly made and protected they have never failed in strength or durability.*

* In 1835 the Water Commissioners of New York adopted a plan recommended by Engineer Martineau for carrying the Croton Aqueduct under the Harlem River by an inverted siphon of wrought-iron of eight feet diameter.

The annexed table of some of these pipes, which have been in use many years, show that long lines have conveyed water under eight hundred and eighty-seven to seventeen hundred and twenty feet head with safety and without showing any evidence of corrosion.

These pipes have been subjected to a hot bath of asphaltum and mineral oil, which is found to be almost a perfect protection against corrosion.

The large pipes proposed for this work, in addition to the asphaltum covering on both sides of the metal, will be provided with a lining of brick, laid in hydraulic cement mortar, which besides protecting the inside asphaltic covering from the wear of the running water, will give the required stiffness against collapse, when the pipe is not filled with water." *

* Messrs. Schussler and Moore, engineers of San Francisco, have planned and made some large and strong wrought-iron pipes for the water works of that city and for conveying water over the crests and valleys of the Sierra Nevada for hydraulic gold mining.

The following notes are from Bowie's Hydraulic Mining, vol. 6, of the transactions of the American Institute of Mining Engineers, chiefly obtained from Mr. Moore:

"These pipes are single riveted in the round seams and double in the longitudinal. If riveted with care, such pipes, after being dipped in an asphaltum bath, are excellent, and will last for many years."

"The bath is made of hot pure asphaltum, 16½ per cent., and coal tar, free from oily substances, 83½ per cent."

"The iron (used in California) will stand strains per sectional inch of 7,000 pounds for No. 12 (0.08 inches thick) to 18,000 pounds for ⅜ inches thick.

"The rule for the thickness of the metal is the usual rough one, viz.: the product of the pressure in pounds multiplied by the radius of the pipe in inches and divided by the above co-efficient."

A table of the size and pitch of the rivets for different diameters of pipe and thickness of metal is given:

"At Cherokee (Mine) there is an inverted siphon 12,000 feet long, of wrought iron, 30 inches diameter, which has in one place a pressure equal to 887 feet depth of water. Its thickness at that place is ⅜ of an inch.

"The Virginia City Water Company have a similar siphon of 11½ inches diameter, which has in one place a pressure equal to 1,720 feet depth of water, with a thickness of ⅛ of an inch. A second siphon of 10 inches diameter, lap-welded, has been laid alongside of the first one. The former withstood an applied pressure of 1,400 pounds per square inch (more than 3,200 feet head).

"Automatic air-cocks are provided, which allow the escape of air from the pipe when filling, and to prevent a collapse when the water is suddenly drawn off.

Careful attention has been directed to the plans for conveying the water from the west to the east side of the Hudson, and the maintenance of the supply uninterruptedly.

Similar river siphons have been repeatedly laid down in Europe and also in this country. Notably on the water works of Glasgow, nearly three-quarters of a century ago, and a dozen years since, under the Charles river at Boston. No failures have occurred in any of these numerous under-river pipe crossings.

More than thirty years ago, I carried a large wrought-iron pipe under the Chicago river for the main water supply of the city, and am informed that it has never failed to perform its functions, and even now is intact.

The greatest depth of water at the proposed crossing of the Hudson is nearly fifty feet, and the water surface over the line of the pipes is a mile in length.

The length of the submerged pipes will be about three-fourths of a mile. The several lines will be placed several hundred feet apart for greater security.

Pipes of wrought-iron can be protected against the corrosion of salt water and against injury from the dragging of anchors, but I have preferred to use those of cast-iron of smaller size covered with asphaltum, and protected from anchors by trenching and covering with large rubble stone.

I propose to make them of unusual thickness, which, besides giving greater strength and immobility, will allow considerable oxidation to occur, and still leave them amply strong at the end of a century or two.

There are numerous cases where cast-iron in the form of pipes, hollow piles, etc., has been subjected to daily alternate

These cocks are also placed at the crests of the direct siphons, and in some instances a stand-pipe is erected at some distance from the inlet to catch and allow to escape the air which travels along the top of the pipe.

Blow-off cocks are required at the lowest part of each of the inverted siphons to discharge any sedimentary matter which may collect there, and to draw off the water from the pipe, when required for examination.

The conduit pipes can be easily tested for tightness, and the precise place of a leak determined, at the numerous places where they undulate over the irregular grades of the route.

wettings from salt water, for a quarter of a century or more, without showing any loss of weight or injury.

It is found that cast-iron which has all of the carbon combined with the iron, is of homogeneous quality, and with smooth surfaces, resists corrosion; while that which is not of uniform quality, or which has rough or pitted surfaces, or when there is some of the carbon uncombined, rapidly oxidizes and is changed in places into a soft graphite. The proposed pipes will be made of the anti-corrosive metal above described, and, with the asphaltum protective covering, may be considered as safe for more than a century.

These pipes will be provided at proper distances with flexible joints in the vertical plane, to allow them to be put together on the deck of barges firmly anchored on the line, and lowered into a trench dredged below the bed of the river.

A strong triangular frame of wood will be provided, in which the pipes will be placed so that they will descend to the bottom without strain upon the flexible joints. The sloping sides of this frame will be planked on each side, so as to carry the flukes of dragging anchors over the pipe without injury to it.

The frame and pipes will also be covered with a mass of heavy rocks, closely packed in, into which the anchor flukes cannot be forced in dangerous proximity to the pipes.

It is also proposed that each pair of pipes shall be laid in lines, separated several hundred feet from each other, to further insure the maintenance of the supply through one pair, if the other should be disturbed.

With all of these precautions, it can be safely stated that there will be no danger of an interruption to the supply of the Ramapo water to the city from any failure of these river pipes.

Every precaution will be taken to prevent sedimentary matter from entering the river pipes, but if any such matter should at any time gather in the lower part of the river siphon, it can be removed in one of several different simple methods.

THE GENERAL PLAN DESCRIBED.

Dams, generally of stone masonry, will be built at or near the outlet of each of the lakes, so as to retain and control the waters stored therein.

Earthen dams will be built at suitable places to form storing reservoirs, and gate chambers and pipes will be made to draw off the water therefrom as it is required.

The following table furnishes information in regard to the location, dimensions, and available contents of these lakes and artificial reservoirs:

Names of Lakes.	Elevation above Tide, feet.	Area of Water-Shed, acres.	Area of Lake, acres.	Average available Depth, feet.	Contents. Available Gallons.
Alpine Lake, Stony Brook.....	962	1,340	59	30	450,000,000
Carr and Two Island Lakes...	710	1,600	106	20	690,000,000
Forest Lake, Otter Creek......	976	842	149	12	540,000,000
Parrott Lake, "	962		126	15	540,000,000
Long Lake, near Monroe	709	1,543	110	..	506,250,000
Round Island L'ke, near Monroe	675		98	15	
Mount Basha Lake...........	845	1,624	280	12	1,125,000,000
Truxcedo Lake....	533	4,818*	293	20	1,875,000,000
Sterling Lake...............	770	3,026	340 5	18	2,025,000,000
Portake Lake...............	620	2,300	100	11.5	750,000,000
Totals..................	...	17,093	1,661.5	..	8,501,250,000

* Truxcedo Lake will be used to store the water from the creek below Sterling Lake, which has 1,834 acres of water-shed, which is included in the above 4,818 acres.

STORING RESERVOIRS.

NAMES OF RESERVOIRS.	Elevation above Tide, feet.	Area of Water-Shed, acres.	Area of Lake, acres.	Maximum of Depth, available feet.	CONTENTS. GALLONS.
Billymac, on Stony Brook.....	790	9,500	138	47	903,750,000
Lower, "	444		97	..	702,500,000
Pine Meadow, "	750	750	69	..	225,000,000
Parrott, Otter Creek.....	790	1,929	74	55	430,000,000
Jackson	610	925	98	40	343,125,000
Townsend, Mt. Basha Creek...	630	2,791	140	50	733,125,000
Barlow.....................	...	3,000	68	60	262,500,000
Lorillard, Truxcedo Creek....	...	2,490	69	45	422,500,000
Noble, Sterling Creek.........	600	....*	50	50	175,000,000
Greenwood, Main River.......	530	15,000	300	..	1,500,000,000
Southfield, "	474		528	..	2,857,500,000
Augusta, "	432		28	..	22,500,000
Summit Cut, Conduit Line....	420	200	14	..	26,250,000
Totals....................	...	36,585	1,663	..	8,603,750,000
Totals of Lakes and Reservoirs	...	53,678	3,325	..	17,105,000,000

The water which will be collected in these lakes and reservoirs (except those on Stony Brook and Portake), when drawn off, will pass down the tributaries and main river, and be intercepted by the Augusta dam and turned into the conduit, which will commence at that place. Independent pipes will be used to convey the water from Stony Brook and Portake Lake to the main conduit.

The conduit will generally follow along the Erie Railroad, first on the east and then on the west side for six and three-quarter miles to Suffern; thence along the Piermont branch for one and a half miles, and then on a line from one-quarter to a mile north of the line between the States of New York and New Jersey, for fifteen miles further, to the Hudson river.

* The water-shed of Noble Reservoir is included with that of Truxcedo Lake.

The water will be conveyed across the Hudson nearly at right angles to its east shore, at the north end of Hastings; from thence the conduit will be continued to and through the Sawmill valley for six and three-quarter miles, to the north line of the city.

The whole length of the conduit, including the river crossing, will be thirty-one miles.

Each of the conduits will be seven feet in diameter in the clear, from Augusta to the west end of the tunnel, a distance of 13.18 miles, with an hydraulic slope of fifteen inches per mile.

The tunnel will be one-quarter of a mile long, and ten feet clear diameter, with a fall of half an inch.

Each of the conduits from the east end of the tunnel to the city line (except in crossing the river) will be five and a quarter feet clear diameter, for the 16.31 miles, having an hydraulic slope of 6.29 feet per mile; and each pair of the river pipes will be four feet diameter.

Each of the conduits will be capable of delivering from sixty-five to seventy millions of gallons a day.

The pipe conduits will, to a considerable extent, follow the general undulations of the ground over which they are laid, but such grades will be given as will reduce the number of direct and inverted siphons as much as possible. This will increase the expense of the grading, but will add to the convenience and effectiveness of the work.

The stone dams at the outlet of the lakes will be built of hammer-dressed masonry, and provided with gates for drawing off the water, and ample waste weirs for carrying off the excess of the greatest floods.

The top of the earthen dams for the reservoirs will be carried up to ten feet above high water, and will be fifty feet thick at the top water line. The water slopes will be from two to two and a half to one, and the rear slope one and a half to one, where made of rock, or two to one where made of earth.

Ample waste weirs will be made at each.*

A gate chamber of masonry will be made near the foot of the inner slope of the dam, and provided with four gates, to enable the water to be drawn off at such depth as it is most pure.

Heavy cast-iron pipes will be laid upon a wall of masonry, and extend through the dam from the upper to the lower gate chamber.

Each of these pipes will be provided with stop gates. Two of these pipes are termed waste and two supply pipes, but each and all of them can be used at will for either of these purposes.

The bed-rock will be found in the valleys at from four to twelve feet below the surface at all these dams, except one.

The rock generally shows itself at the surface on the sides of the valleys, where the dams are to be built.

Great care will be taken to make a water-tight connection between the artificial earthwork of the dam and the bed-rock, by roughing all of its surfaces and by cut-off trenches sunk in the rock.

These rock trenches, and the side benches, will be filled with puddle or very rough-surfaced masonry.

Sand, gravel, loam and clay is to be found at all of the reservoirs, and these materials will be mixed in proper proportions, put on in thin layers, and wet and rolled, until the mass is made compact and impenetrable by water.

The water-face of the banks will be lined with a heavy slope wall, to resist the action of the waves in the reservoir.

The lower half of the embankment will generally be made of boulders from the excavations, which will be mixed with stone and coarse gravel and rendered solid.

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* To determine the size of the water weirs, it was assumed that the greatest known rainfall might occur in mild weather, when there was a large body of snow upon the frozen ground, which would melt and increase the body of water, and that the reservoirs were at such time full, and then that the length of the waste would be half as large again as that necessary to prevent the flood filling the reservoirs within six feet of the top of its earthen banks.

Comparative estimates have been made of the cost of building the reservoir dams of masonry and of earth.

Stone of the best quality is found at or near all of the dams, and the foundations could generally be made upon rock, at no great depth below the surface.

It has been said that stone dams are more safe than those of earth.

It is true that if the water from the reservoir should ever make a leak through an earthen dam, or rise high enough to overtop it, there would be great danger of its being carried off and cause great destruction of property and endanger human life.

The stone dam, on the other hand, would not be in much danger of breaking away either from leaks or the overflow of the water.

An earthen dam, made as herein provided, will not leak, and the large self-acting waste weirs will prevent any overflow.

Thus made, it is as safe as a stone dam and will be more tight, and it is less expensive.

Under the circumstances of the case, I prefer the earthen to the stone dam.

When the supply water is discharged from the lakes and reservoirs, it will (except in two cases) flow down the brooks and main river, to the entrance of the main conduit at Augusta.

In times of flood, the water flowing down the brooks and river will be somewhat turbid, and on such occasions the city supply will be taken from Stony Brook and Portake Lake, and, if desired, from two of the other sources, and their clear waters will be conveyed by pipes directly into the main conduit.

It is also proposed to use the summit deep cut of twelve thousand feet length as a settling and aerating reservoir.

These arrangements will assure the delivery to the city of pure clear water at all times.

It will be seen from the map and profile that the main conduit, east of the tunnel, crosses several valleys. It is proposed to build equalizing reserve reservoirs in one or more of these valleys, into which the surplus water not required for the city will be conveyed by a pipe from the main conduit, and held in reserve until it is required for use. Such reservoirs can be made to contain four hundred millions of gallons, which could be availed of, with a loss of thirty or forty feet head, which, on the occasion of their requirement, would be unobjectionable. That is, the supply from these reserves would for a few days be delivered to the city at two hundred and sixty to two hundred and seventy feet above tide level.

A site for a similar equalizing reserve reservoir has been found along the route of the main conduit in Westchester county, a few miles north of the city line.

The cost of building these equalizing reservoirs has not been included in the estimates, as they are not deemed absolutely necessary for the Ramapo project, but the idea is now presented to show what might be done in the future for its complete development.

The project has been arranged for the delivery, at first, of fifty millions of gallons of water a day, at the north line of the city, at an elevation of three hundred feet above tide level.

For this purpose it will be necessary to build the dams at the outlet of Windermere, Round Island, Forrest, Greenwood, Alpine, Mt. Basha, Truxcedo and Sterling Lakes, and the artificial reservoirs of Townsend's, Billymac's and Noble's, which will have an aggregate water-shed of forty square miles, embracing only tributaries of the River Ramapo.

The water from these lakes and reservoirs will be conveyed in pipes to the main conduit, and the latter will be built down the valley of the Ramapo, to Suffern, and thence, upon the route already described, to, across, and on the west side of the Hudson river to the city line.

The main conduit will be three feet in diameter for ten miles from Monroe to the entrance of the pipe from the Truxcedo; from thence to the tunnel, fifteen and one-quarter miles, it will be four and one-quarter feet in diameter, and east of the tunnel to the city line, seventeen miles (exclusive of the river crossing), it will be five feet in diameter. Two

cast-iron pipes, each of four feet in diameter, will convey the water across the Hudson river.

The branch pipes from the lakes and reservoirs will be of the following dimensions:

	Miles.	Ft. diameter.
From Round Island Lake	0.60	2
From Jackson Reservoir	0.15	2
From Otter Creek	1.50	2
From Townsend Reservoir	0.50	2
From Truxcedo Lake	1.00	3
From Billymac Reservoir	2.00	$2\frac{1}{2}$

The surface level of the water in Round Island Lake will be six hundred and seventy-five feet above the level of tide, and the pipe therefrom will have a descent of seventy-five feet to the intersection of the main line, and also the one from the Jackson Reservoir at Monroe.

The main conduit will have a descent of fifty feet from the above intersection to opposite the mouth of Otter Creek, where the pipe from its lakes will enter the main conduit. Below this the conduit will have a descent of fifty feet to the intersection of the pipe from the Townsend Reservoir, and a further descent of fifty feet to the intersection of the pipe from Truxcedo Lake, and a still further descent of twenty-five feet to the intersection of the pipe from the Billymac Reservoir at Stony Brook. After which the main conduit will descend fifty feet to the tunnel, and then one hundred feet more to the city line, where the water will be delivered equal to an elevation of three hundred feet above tide.

From the table on page 18, it will be seen that the reservoirs, lakes, and streams from which the branch pipes start are all at different levels. Automatic valves will be placed in each of these branch pipes near their intersection with the main conduit, so as to admit the water from each at the same pressure as that in the main conduit, at the intersection, and also to prevent the water from the higher sources emptying themselves into the reservoirs of less elevation.

The increased head and greater slope which the above arrangement will give to the water flowing down the main conduit, greatly reduces its size from that arranged for the hundred-million-gallon plan starting from the Augusta dam.

It will sometimes be necessary to diminish or wholly stop the flow of the water in the main conduit for a short time. In such cases the whole length of the conduit (and of the branch pipes) will be subjected to the head due to the elevation of the reservoir with which the conduit is, for the time being, in connection.

The highest of these sources is that of Round Island Lake, 675, and the lowest is Truxcedo, 530 feet above tide.

Wherever the conduit descends into the valleys, the extreme pressure of the water on the pipe will be the difference of level between it and the source.

Equalizing valves will be placed in the main conduit at the intersection of the Truxcedo pipe and at the tunnel, so as to reduce the head in the conduit to 530 feet above tide at the former and 400 feet at the latter.

The thickness of the metal on all of the pipes has been arranged with reference to three times the pressures to which they will be in each case subjected, to allow for the dynamic pressure which a sudden check in the flow of the water would cause.

For the first plan for a daily supply of fifty millions of gallons, all of the lakes except Carr and Portake will be brought into use, and also the upper reservoir on Stony Brook and at Townsend's.

These sources will have a little more than forty square miles of water-shed.

LONG HOUSE BROOK—MODIFYING THE FIRST PLAN.

The most valuable of the water-sheds, outside of the Ramapo, is that of Long House Brook, a tributary of the Walkill, lying just west of the Ramapo.

There is a lake of one hundred and fifty acres area at the upper end, which has two thousand acres of water-shed. A depth of twenty feet over the lake gives a content of nine hundred and eighty millions of gallons. The principal reservoir, one and a half miles below the lake, will have a water-shed of three thousand acres, and with the water thirty feet deep at the dam, its content will be seven hundred and fifty millions of gallons.

The lower reservoir, one mile below, will have a water-shed of one thousand four hundred acres, and the content will be two hundred and fifty millions.

Making a total area of water-shed of six thousand four hundred acres, and a storage of nearly two thousand millions of gallons.

The surface of the lower reservoir will be one hundred and twenty-five feet above Long Lake, and the pipe between them will be eight miles long.

Long and Round Island Lakes will be connected by a stone conduit one thousand seven hundred feet long, so placed as to draw off ten feet of the water of Long Lake, and its dam will be built so as to raise its water ten feet, thus providing for a storage of twenty feet depth over one hundred and twenty-five acres.

The dam across the outlet of Round Island Lake will be fifty feet high, so as to maintain the waters of both lakes at the same level for the upper twenty feet, but the delivery gates will be arranged to draw off the whole fifty feet depth of water from the lower lake.

The available storage of these two lakes will be three thousand million of gallons.

The pipe from Long House Brook will be two feet nine inches in diameter, and will discharge thirty cubic feet per second, which is fifteen times as much as the mean supply of water from that district; but in great floods or after long-continued rains the quantity of water will, for a comparatively short time, exceed the capacity of this pipe.

On such occasions the surplus water will be retained in the lake and reservoirs of Long House Brook, until the discharge of the conduit pipe again exceeds the flow of water from the district, and then the water which has been stored therein will be gradually transferred to Long and Round Lakes, and the empty reservoirs on the brook will be in condition to store fresh supplies from subsequent heavy or protracted rains.

In this manner abundant provisions for storage will be made for all of the water which falls upon the water-shed of Long House Brook.

There is a further water-shed of about three square miles of this brook, which can also be introduced into the Ramapo supply, but at a cost proportionately greater than that above described, and it should be considered whenever it becomes necessary to largely increase the supply from the Ramapo.

The pipe conduits from Round Island Lake to the entrance from the Truxcedo are required to be larger than on the first plan, but below that junction the works of both plans are alike.

The first fifty millions of gallons a day will be obtained on the Long House Brook plan, without resorting to Sterling Creek or Lake.

The whole cost is about the same as for the first plan.

THE DISTRIBUTION OF THE RAMAPO WATER THROUGH THE CITY AND ITS APPLICATION TO THE EXTINGUISHMENT OF FIRES.

All of the street pipes which are now laid in the annexed districts, and on Fort Washington above the level of 100 feet above tide, are strong enough to stand the direct pressure from the Ramapo (300 feet above tide), and they may all be disconnected from the Croton system and supplied with the Ramapo water.

If a single line of pipes of two feet in diameter is laid for fire purposes, from the north line of the city to the Battery, with cross pipes of the same size each way to the North and East rivers, and if they are not tapped for other uses, it will

supply as much water to the fire hose everywhere along such main and cross pipes as is now used by twenty-five to thirty steam fire-engines in constant work at a fire, and with from 150 to 200 feet head above tide level, or it will furnish ten such streams deliverable under 275 feet head. That is, the fire-hose taken from these pipes, without the aid of fire-engines, will throw ten such streams of water more than 100 feet above the level of the highest street on Murray Hill, and to still greater heights elsewhere.

But these fire mains, when not required for that purpose, may also be used to increase the head and quantity of water now delivered from the Croton by the present street pipes to any desired extent, by connections near the extremities of the street pipes, or wherever the demand for water exceeds the capacity of the present pipes.

All such connections would be provided with an automatic regulating valve, by means of which the Ramapo water will be admitted in such quantity and under such head as each of the cases require.

If the proposed fire mains should be connected with the existing pipes, as above stated, it would sometimes (as in a great fire) be necessary to temporarily shut off the connections and leave the whole Ramapo supply to be applied to their extinguishment. Whenever the advantages of the increased head and supply to the now deficient portions of the city have been experienced, it is reasonably certain that a demand will be made for other supply pipes, which will be independent of the fire mains, so that these advantages will be maintained without interruptions.

It will be understood that the water everywhere in the fire mains will always stand with a pressure equal to three hundred feet above tide, until it is withdrawn for use at a fire, and then it will generally stand with a pressure of at least two hundred feet head, and during the heaviest draft at great fires will continue at from one hundred and fifty to two hundred feet head, depending upon the quantity of water withdrawn, and the distance from the north city line.

The limited quantity of water which is delivered at the southern end of the city, and its low head, has long been a source of complaint, and for some years past has partially been corrected by carrying down large independent untapped mains from the Central Park Reservoir to the City Hall Park, at a very large expense.

The superior head of the Ramapo (three times that of the Croton) will permit the use of much smaller pipes to accomplish this desired object, and consequently much expense will be avoided in the future.

In fact, one or more of the independent mains already laid can be applied to the conveyance of the Ramapo water to the lower district with economy, and vastly increase its usefulness.

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Respectfully,

WM. J. McALPINE.

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