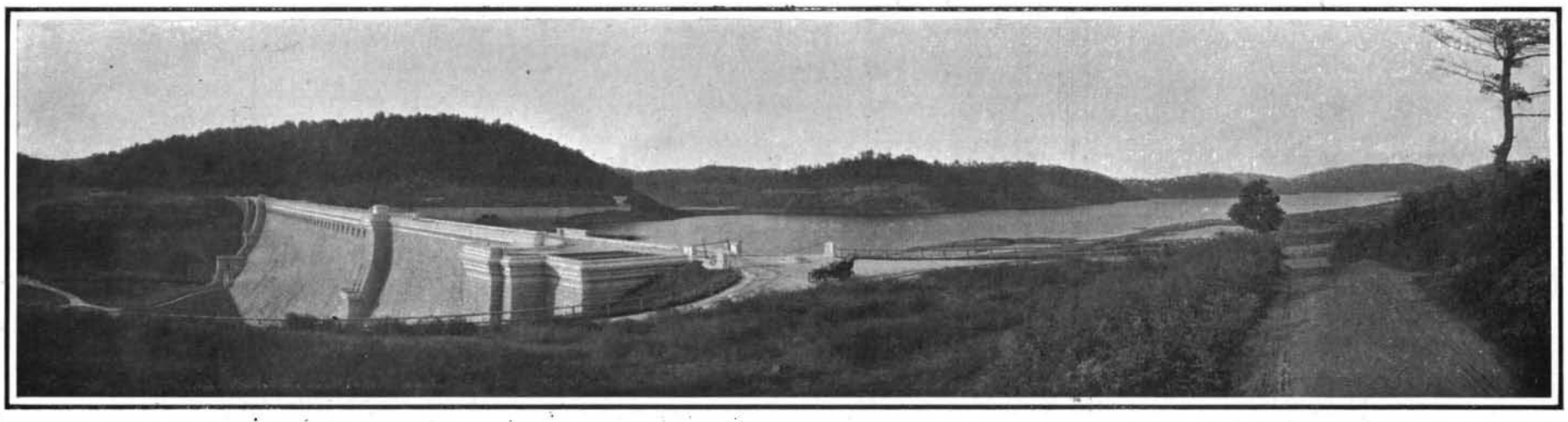
WATER SUPPLY

DEVELOPMENT OF THE CROTON WATERSHED.

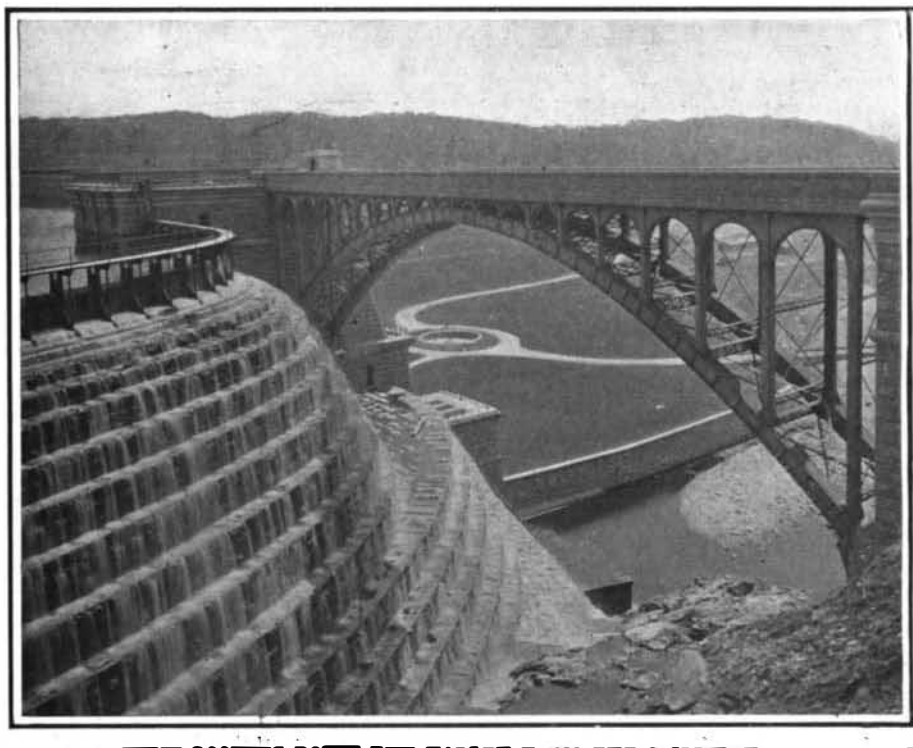
It was not until the middle of the last century that New York city undertook the construction of a system of water supply on a scale of any magnitude. After an investigation of the available watersheds, it was decided to develop a system of reservoirs in the valley of the Croton River, which flows into the Hudson from the east at a point about 35 miles distant from the City Hall. A dam 50 feet in height was built across the Croton River at a distance of about four and a half miles from its mouth, and the fresh-water lake about four miles in length thus formed, provided a supply of about two hillion gallons of water. From the lake an aqueduct 8 feet 5½ inches high by 7 feet 5 inches wide and 38 miles long was built to carry the water to the city, where it was delivered to a distributing basin known as the Murray Hill reservoir, located on Fifth Avenue, between 40th and 42d Streets, which had a capacity of 24 million gallons. This work included the construction of a noble aqueduct across the Harlem River at Highbridge, which forms one of the most interesting engineering monuments in this city to-day. In its 1,450 feet of length are fifteen 80-foot and seven 50-foot arches, the under side of which is 100 feet above tide level. The new works were formally opened June 27, 1842. At that time the population of the city was only 350,000, and the consumption was 12 million gallons a day. As the aqueduct had a capacity of 90 million gallons, it must have looked to the good citizens of those days as though provision had been made for a future far removed. New York city, however, grew apace; and to meet the increased demands new reservoirs were built from time to time farther up the valley of the Croton and its tributaries. Before another half century had passed the water consumption had increased to a point where the authorities were confronted with the necessity for constructing another aqueduct. It was decided to build the new conduit of such a size that in conjunction with the old aqueduct it would be capable of delivering an amount of water about equal to the annual average daily flow of the Croton River. The New Aqueduct, as it was henceforth to be known, is built of brick. It is of a horseshoe section, measures 13 feet 6 inches in height by 13 feet 3 inches in width, and it is capable of delivering 300 million gallons of water daily. It was opened in June, 1890.

At this stage of development of the water supply the capacity of the aqueduct was, of course, greatly in excess of the capacity of the reservoirs in the Croton watershed; although these were continually increased in number to meet the growing demands of the city. About twenty years ago, however, it was realized that a large addition must be made to the existing reservoirs to meet the growth of population,

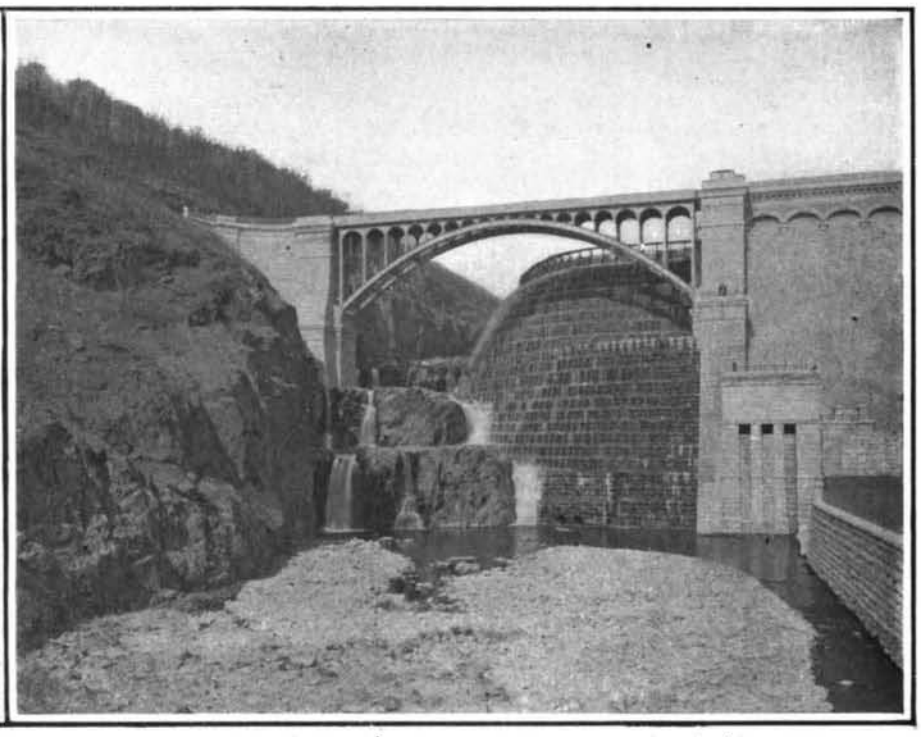


The line of the 1,000-foot spillway is seen on the far side of the lake. This panorama was taken with a Cirkut camera.

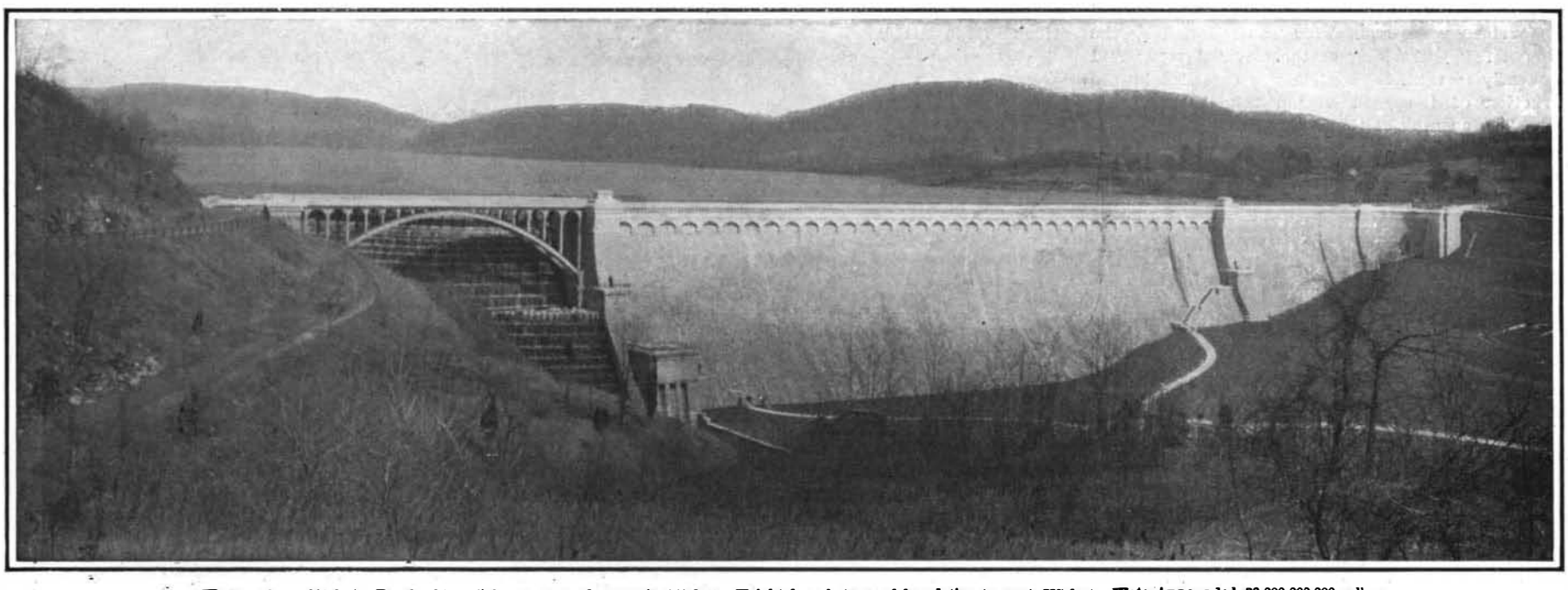
CROTON RESERVOIR FROM THE HILLS TO THE SOUTH OF THE DAM.



VIEW LOOKING DOWN THE VALLEY FROM THE SPILLWAY.



LOOKING UP THE SPILLWAY FROM THE NEW BED OF CROTON RIVER, BELOW THE DAM.



Width at base, 216 feet. Depth of base below bottom of reservoir, 140 feet. Height from bottom of foundation to crest, 297 feet. Water impounded, 30,000,000,000 gallons.

VIEW OF THE CROTON DAM AND LAKE FROM DOWNSTREAM.

which was advancing at a rapidly increasing rate. After a thorough investigation of the problem, it was decided to build an enormous dam of unprecedented height across the lower Croton valley, at a point about two miles from the mouth of the river, and create a large artificial lake about 20 miles in length, capable of impounding 30 billion gallons of water. Ground was broken in 1902, and after thirteen years of work, in which several years' delay was caused by a revision of the plans when the dam was partially completed, this great structure was opened (or, to speak more strictly, the gates were closed) and the dam began to fill on January 28, 1905.

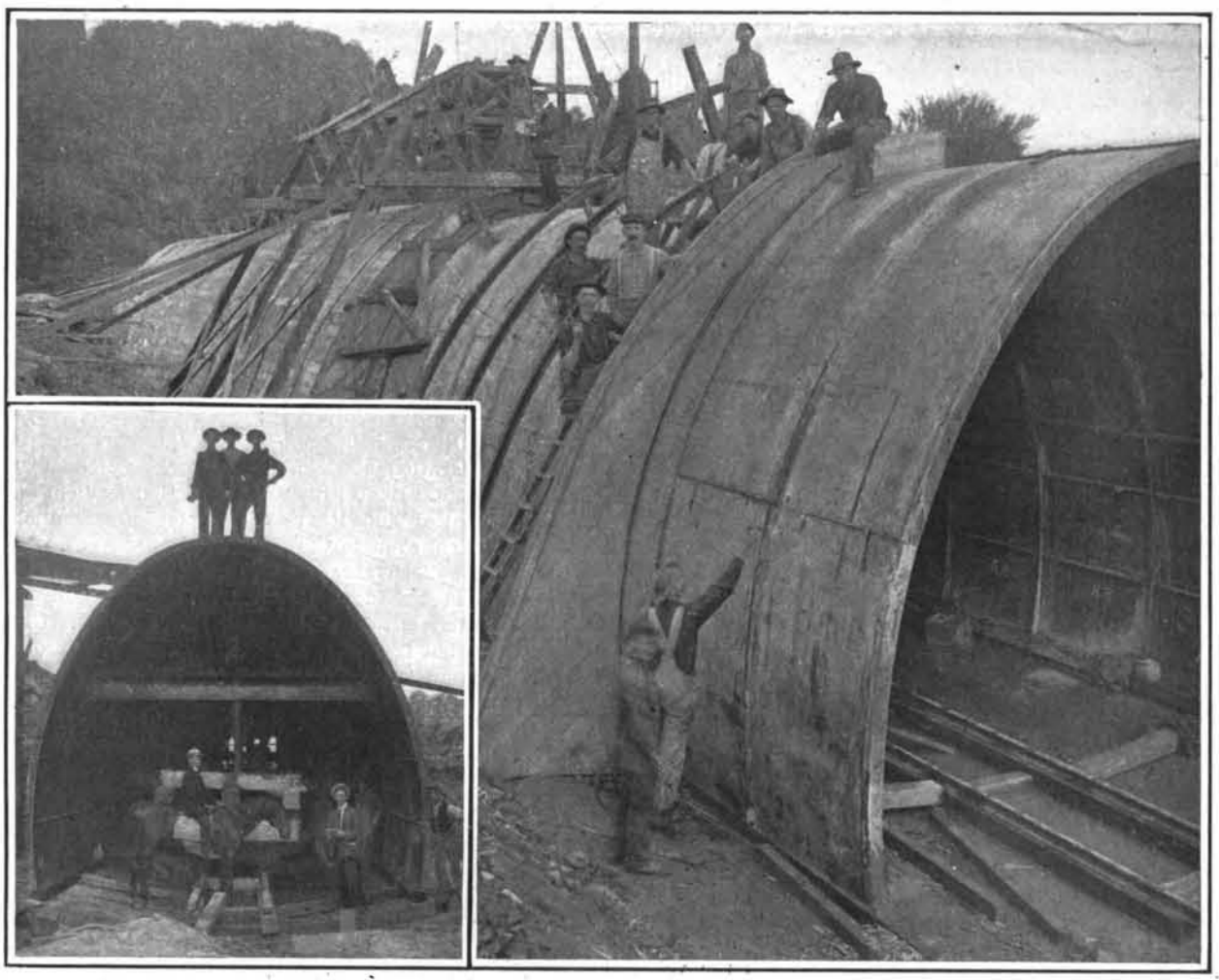
The construction of the dam necessitated an enormous amount of excavation before rock bottom of a sufficiently solid character to support a structure of this size, and preclude the possibility of seepage below the dam, could be found. A huge trench was dug across the valley and carried down to a maximum depth of 131 feet below the original bed of the river, the width of the trench at the lowest point being about 250 feet. The work of excavating was commenced in 1892 and completed in 1896, and during this period 1,175,000 cubic yards of material was taken out. The dam as originally designed consisted of three portions. The first 400 feet on the southern side of the valley was to be an earth dam with a masonry core wall; then was to follow 650 feet of masonry which was to be continued upstream parallel with the side of the valley to form 1,000 feet of spillway. Subsequently, when the dam was approaching completion, it was decided to substitute solid masonry for the earth-and-core wall section, and make the dam a homogeneous structure of masonry throughout its whole length. As finally constructed and shown in the accompanying engravings, the dam proper extends across the valley for a distance measured on its crest of 1,168 feet, until it is within about 200 feet of the southern side of the valley. Here it swings around and is continued up the valley for a further distance of 1,000 feet; finally turning in to a junction with the native rock of the hillside.

It is when we come to examine the cross section of the dam that its colossal proportions are manifest. Its foundations, at the widest part, are 216 feet in width, and the height from the foundation rock to crest is just under 100 yards, or, to be exact, 297 feet. The upstream face has a slight batter. The downstream face curves upwardly from the bottom width of 216 feet to a width at the top of 18 feet. The lowest point of the foundation is 131 feet below the bed of the river, and the top of the dam is 166 feet above the river bed. When the dam is full the depth of the water at the upstream face of the dam is 160 feet. The gap between the masonry dam proper and the side of the valley, forming the spillway channel discharge, is spanned by a handsome steel arch bridge, which serves to carry one branch of the system of roads which has been built around the reservoir, an important link in which is the driveway which extends across the valley along the crest of the dam. The overflow from the reservoir flows into a channel which has been blasted out between the masonry of the spillway and the rock of the hillside, and is conducted down to the old bed of the river below the dam over a series of roughly hewn steps in the rock, the water falling in a great cascade, 140 feet in height and issuing into the lower valley beneath the steel arch above referred to.

At the point in the main dam where it begins to curve into the spillway is located a gate house, in which are three 48-inch pipes controlled by gates which, during the construction of the dam, were left open to permit the Croton River to flow through, and in future will be used to draw off the waters of the dam for purposes of inspection and cleaning.

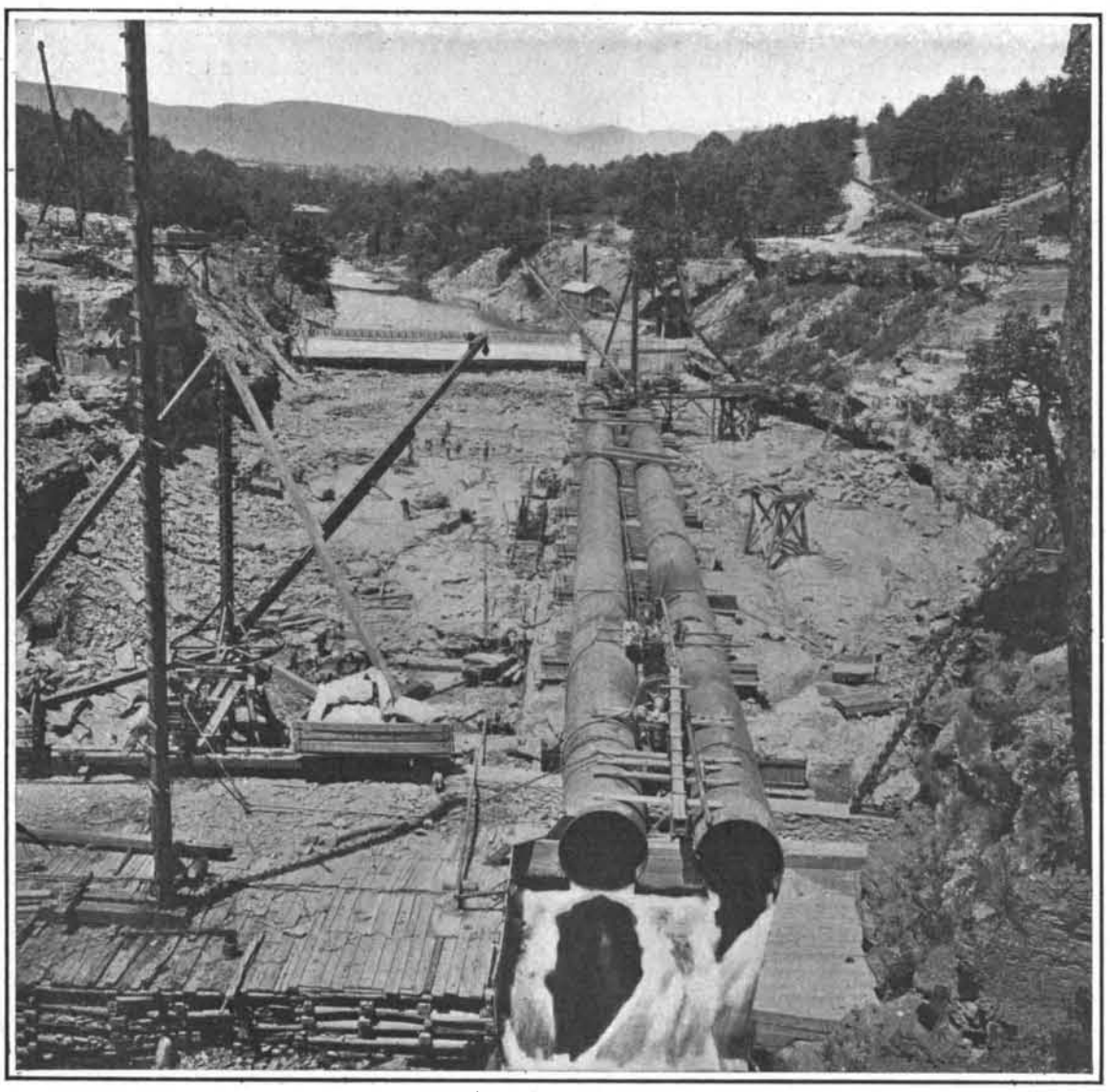
It will readily be understood that the work of building the enormous mass of masonry represented by this mammoth structure was a slow and costly work. An excellent quality of rock was found a few miles up the valley, from which the quarried rock was brought down on cars and delivered along the whole site of the dam either by overhead cableways or by means of derricks distributed in large numbers over the whole face of the work. The greater part of the dam was built of large rock weighing up to five tons apiece, the interstices between which were filled in with smaller rock and cement laid by hand. The southerly end of the dam, which replaced the earthen core-wall dam first proposed, was built by a new method, in which the large masses of rock are dropped into a bed of liquid concrete, the concrete taking the place of the hand-laid smaller rock as used in constructing the earlier portion of the dam. The total amount of masonry in the finished dam is 850,000 cubic yards; and as the preliminary excavation of the trench involved taking out 750,000 cubic yards of earth and 425,000 cubic yards of rock, the magnitude of the work will be appreciated. As the masonry rose in the trench, the better quality of earth which had been excavated was brought back and filled in against the dam on both upstream and downstream faces, the downstream side being finished off in broad, easy slopes, and an attempt at landscape gardening being made by the erection of a fountain and the construction of winding roads. This last work, however, is somewhat crude, and it is to be hoped that at some future day the city will take this matter in hand, smooth down the unsightly banks of excavated material, plant the hillsides with trees and shrubbery, and render the approach to this truly magnificent structure worthy of its dignity and importance.

At high water level the crest of the old Croton dam, built in 1843, is buried 30 feet deep by the reservoir formed by the new dam; and at this point is located the principal gate house through which the water is led into the old and the new aqueducts. The creation of a lake that backs 20 miles up the Croton Valley



This huge conduit, 17 feet 6 inches high by 17 feet wide and 90 miles long, will convey 500,000,000 gallons of mountain water per day from the Catskills to New York City.

CONSTRUCTION OF THE CATSKILL AQUEDUCT.



During construction the flow of the river is conducted across the site of the dam in two 8-foot steel pipes.

PREPARING THE FOUNDATIONS FOR THE ASHOKAN DAM, WHICH WILL IMPOUND 179,000,000,000 GALLONS OF WATER.

necessitated an entire relocation of the systems of roads and the construction of a large number of costly bridges to carry these roads over various arms of the lake. These crossings include a 124½-foot bridge; two spans of 217 feet; one of 310 feet, one of 396 feet, and

MAP OF CATSKILL AND CROTON WATERSHEDS, SHOWING THE NEW CATSKILL AQUEDUCT.

a handsome cantilever structure with a central span of 384 feet. The system of new roads extends for 50 miles around the lake. These supplemental works, together with the cost of the real estate, etc., brought the total cost of the whole scheme up to a round sum of about $12,000,000.

During the construction of the new Croton dam the city undertook the building of the Jerome Park reservoir, lying near the northerly limits of New York city, which is designed to act as a storage and distributing reservoir within the city limits. The reservoir as designed has an area of 239 acres and a depth of 26½ feet. The excavation involved the taking out of about 11 million cubic yards of material, most of it rock. It is divided by a wall that runs through it in a north and south direction; and the easterly half, which has been completed and entirely lined of concrete, has a maximum full capacity of 773,400,000 gallons.

Subsequently to the completion of the Croton dam a large reservoir known as Cross River, holding 10,308 million gallons, has been completed, and another, the Croton Falls reservoir, with a capacity of over 14 billion gallons, is under construction. When the last-named is completed there will be ten separate dams in the Croton watershed, with an aggregate capacity of 104,530 million gallons.

During last winter, from November 6 to March 15, all the reservoirs on the watershed were full and overflowing, and during this period over 80 billion gallons of water ran to waste over the spillway of the new Croton dam. With a view to storing a portion of such waters as would overflow in the future, it is proposed to build one more dam in the upper reaches of the watershed, which will have a capacity of 20 billion gallons and will be known as the Patterson reservoir.

From what has been said it will be seen that the limit of the storage capacity of the Croton watershed has about been reached. The daily average flow of the Croton River during the past forty years has been 402,330,000 gallons. The present daily consumption of water in New York city is about 325,000,000 gallons. Taking into consideration the increasing rate of growth of population of the city, and the fact that the annual increase in water consumption is at present at the rate of 15 million gallons daily per year, it can be seen that within a few years' time the consumption of the city will have exceeded the daily river flow and the capacity of 380 million gallons of the two aqueducts leading from Croton reservoir to New York. As the result of an exhaustive examination by various boards of engineers, it was found that the nearest available source for a new water supply was to be found in the region of the Catskill Mountains; and a gigantic scheme has been approved and is now being carried through for bringing a supply of fresh mountain water into New York city from the Catskills, to the extent of 500 million gallons daily, at a total cost of $161,000,000.

THE CATSKILL WATER SUPPLY.

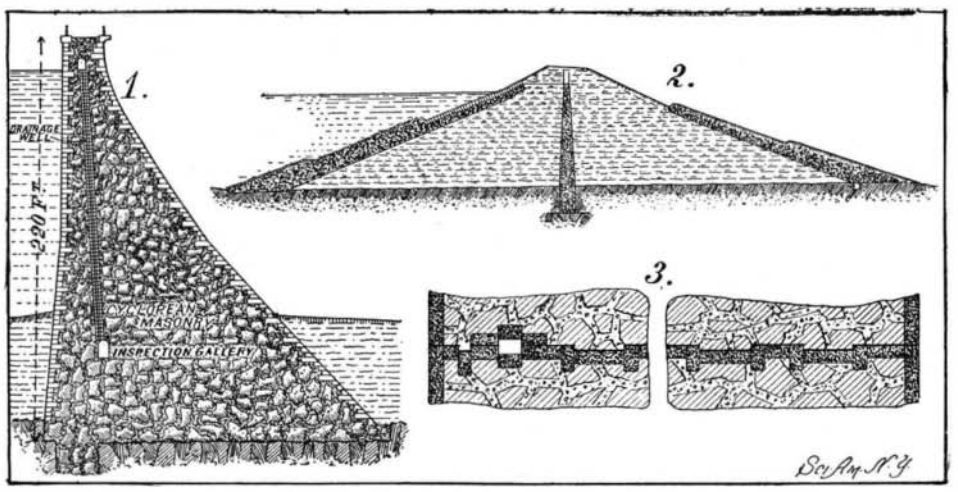
In selecting a new source of water supply the engineers of the board realized that the conditions surrounding New York city were unusually perplexing. To the east the city is shut in by the Atlantic Ocean and to the west it is excluded by the laws of New Jersey from tapping any of the water sources of the State. A most excellent supply might have been drawn from the sources of the Housatonic River, had the district not been excluded from consideration because of its location in the State of Connecticut. Hence, the city has been driven by its geographical and legal restrictions to go far afield in its search, even to the regions of the Catskill Mountains. The disadvantages of distance, however, are compensated by the fact that the watersheds are sparsely inhabited, and that the water supply is not only abundant but is of excellent quality. By reference to the accompanying map, it will be seen that when the whole scheme has been developed water will be taken from four separate districts. The first of these, the Esopus Creek watershed, has an area of 255 square miles. Its waters will be impounded by the construction of a huge dam 220 feet in maximum height and 5,650 feet in length, which will be built across the valley of the Esopus at what is known as the Olive Bridge site. The dam will create what will be known as the Ashokan reservoir, which will be 2½ miles in width, with a full level capacity of 170 billion gallons, and will be capable of supplying the city, with 250 million gallons of water a day.

The rate of growth of Greater New York is so rapid that it cannot be many decades before the watersheds of the Rondout, the Schoharie, and ultimately of the Catskill rivers will in turn be brought into service. The Rondout watershed covers 176 square miles, and would be capable of yielding 130 million gallons daily. This water will be stored in what will be known as the Napanoch reservoir, from which its waters will be led by an aqueduct into the main Catskill aqueduct a couple of miles below the Ashokan reservoir. Later, the Schoharie watershed will be brought into service by the construction of the Prattsville reservoir, its waters being brought into Esopus Creek by means of a tunnel through the divide. Lastly, the Catskill water will be impounded in several reservoirs located along that stream, and brought into the Ashokan reservoir by an aqueduct whose location is shown on the accompanying map. Altogether, when the whole scheme is completed, New York city will have at command over 700 million gallons daily water supply from the Catskill Mountain watershed in addition to the 375 million gallons daily already available in the Croton watershed.

The Ashokan dam, like the Croton dam above described, will take rank as one of the greatest structures of its kind in existence. It will be built partly of solid masonry and partly of earth. The masonry portion, which will extend for about 1,000 feet and occupy the center of the dam, will be built of the general cross section shown in the accompanying engraving. The width of the base will, of course, vary with the depth of the foundations; but at the center it will be not far from 200 feet. Its height taken at the same point will be 220 feet. The earth-and-core-wall portions of the dam will extend from the masonry middle section to a junction with the valley on one side, and some high ground on the other. The total length of the dam will be 5,650 feet. In addition to the dam there will be a series of dikes which will be built across depressions in the country and serve to hold the water at the desired level. Beyond the dikes will be a large waste weir. The dikes will constitute a very important work, for together with the waste weir they will have a total length of 3.8 miles. One of our illustrations shows the preliminary excavation work for the dam and the means adopted for by-passing the flow of the Esopus Creek during construction, which is being done by means of two 8-foot steel pipes which will be sufficient to accommodate the creek at its ordinary level. Subsequently, as the excavation is carried further down, the water will be diverted through a channel formed along the side of the valley. Ultimately, during the erection of the masonry of the dam, the water will flow through a tunnel, which will be left open for that purpose and closed when the dam is completed.

From the dam the water will flow by gravity through a huge steel-and-concrete aqueduct 17 feet in the clear

(*Continued on page 414.*)



1. Cross-section of masonry portion of dam. 2. Cross-section of earth-and-corewall dam. 3. Horizontal section through an expansion joint in dam.

PLAN AND DETAILS OF THE ASHOKAN RESERVOIR AND DAM.

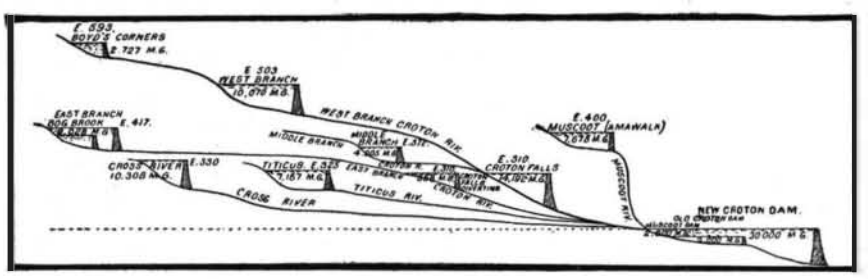
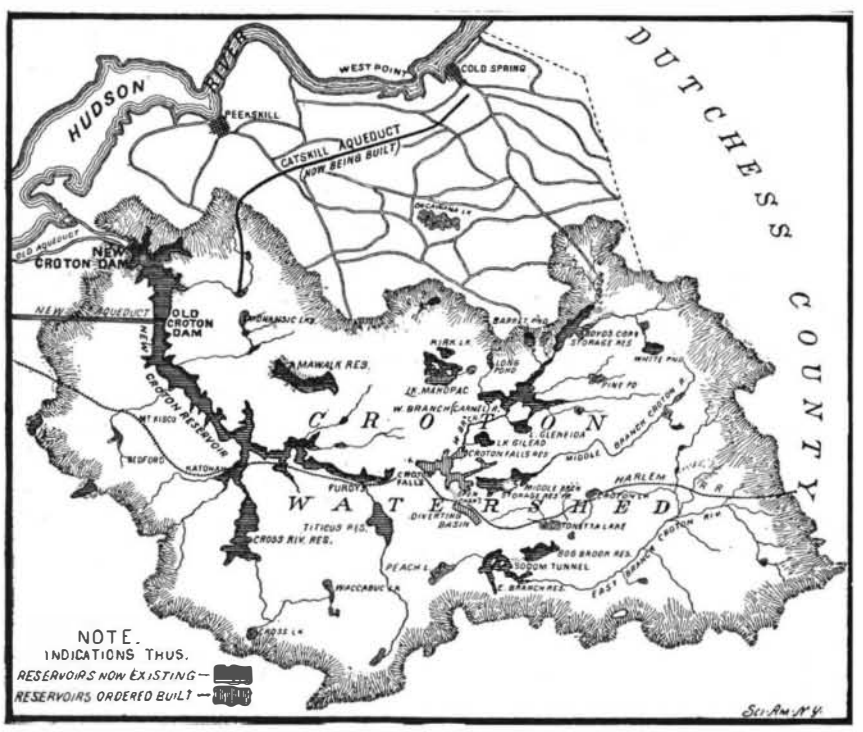


DIAGRAM SHOWING ELEVATION AND CAPACITY OF CROTON RESERVOIRS.



PLAN OF THE CROTON WATERSHED, SHOWING LOCATION OF THE RESERVOIRS.