THE NEW CROTON AQUEDUCT.

ORDINARILY, a dwelling-house, measuring say 33 by 35 feet, and standing where the rainfall is not less than 45 inches in a year, will collect on an average about 90 gallons of water per day; that is, supposing that all the water that falls in the area of the building is saved, that none is allowed to evaporate, and that the cistern is big enough to hold the excess of water that falls in the wet winter months. Practically, such a roof will not give on an average ninety gallons a day, and in a dry year will yield very much less. Such a dwelling-house may be supposed to contain a family of five people, and at even ninety gallons a day this would be only eighteen gallons apiece. A tenement house five stories high and of the usual New York area has about the same roof surface. In such a tenement five families, or twenty-five people, would find homes, and if the theoretical ninety gallons were divided among them, they would have only a trifle over three and a half gallons each.

When in the rapid growth of New York City the population reached three hundred thousand it became necessary to obtain more water than could be supplied by the wells or roof tops. A small supply had been obtained near by, but it was not enough, and it became very evident that the needed water must be brought from some distant water-shed far beyond any injury from the smoke, dust, and refuse of a great city. There were some who looked to the Housatonic Valley in Connecticut. Others thought the pure, deep lakes among the mountains of New Jersey would be nearer and more abundant. Next to these was the valley of the Croton River, about thirty miles north of the city. The Croton was within the State of New York, and its many branches, winding among wooded hills and meadow-dotted valleys, covered over 360 square miles of thinly settled country. It was for these reasons the most available water-shed in easy reach, and was selected as the big roof from which to fill the municipal water-barrel.

The original Croton aqueduct was begun in 1837 and finished in 1842. It is a brick conduit built on or near the surface, and extends from the dam at Croton Lake (which is artificial) along the Hudson River to High Bridge, crossing the deep valley of the Harlem on that beautiful structure—a true aqueduct that suggests the grand aqueducts of Rome. The capacity of the aqueduct is from ninety-five to ninety-eight million gallons of water every twenty-four hours. For the New York of the 'forties this was an abundant supply, and a curious result seems to have followed the use of such a vast quantity of water by such a comparatively small population. Three hundred gallons in a day for each person—no one could use so much water. Why take thought of its use? The people of New York never did, and they became, so far as water was concerned, a wasteful people, and they have never been cured of the habit. Prayers, entreaties, threats, fears of a water famine, have made no impression.

Within the life of one generation the average daily supply of ninety-seven million gallons has come to be insufficient. The people on the lower floors continued to go on in the same cheerful wastefulness, with no thought of their neighbors or of the morrow, until all upstairs New York was reduced to very short commons. Then thousands of small pumping engines were put into the tenements and many roofs carried a water-tank. With the ever-growing population the share of water for each individual has rapidly decreased. The public fountains have been shut off and the use of private hose has been restricted. In 1884 the Bronx River aqueduct was built, and for a while it served to help the upper part of the city. To-day, even with this extra supply, there are only 115,000,000 gallons daily to be divided among 1,500,000 people. Even this apparently liberal supply implies plenty of rain. If the season be dry and the rainfall scant there will be serious trouble at once.

When in the early 'eighties it was proposed to bring more water into the city it seemed best to go once more to the Croton.

Speaking roughly, the Croton River and its branches cover about 360 square miles of hilly country in Dutchess, Putnam, and Westchester counties, New York, and also a narrow strip of the western edge of Connecticut. The main river flows in a southwesterly direction into the Hudson, the lower part following a narrow and winding valley among high hills, the upper portion spreading out into three main channels called the East, West, and Middle branches. It is naturally a country of brooks and ponds, and is musical in spring with the sound of many waters. If the entire surface on which the falling rain seeks an outlet above the present Croton Dam is measured, hills, fields, and lakes, we have 338.82 square miles of available water-shed. Of course all the territory below the Croton Dam is virtually useless as a water-shed. The rain indeed falls, but it flows away and is lost in the salty waters of the Hudson. There are therefore two water-sheds, one the present water-shed above the dam, and the larger district (including the former) below the dam, and which might be used were a second dam built lower down the river. This larger water-shed would give a surface of over 360 square miles. As this lower dam is not yet built, it may be best first to consider the smaller water-sheds now available above the present dam.

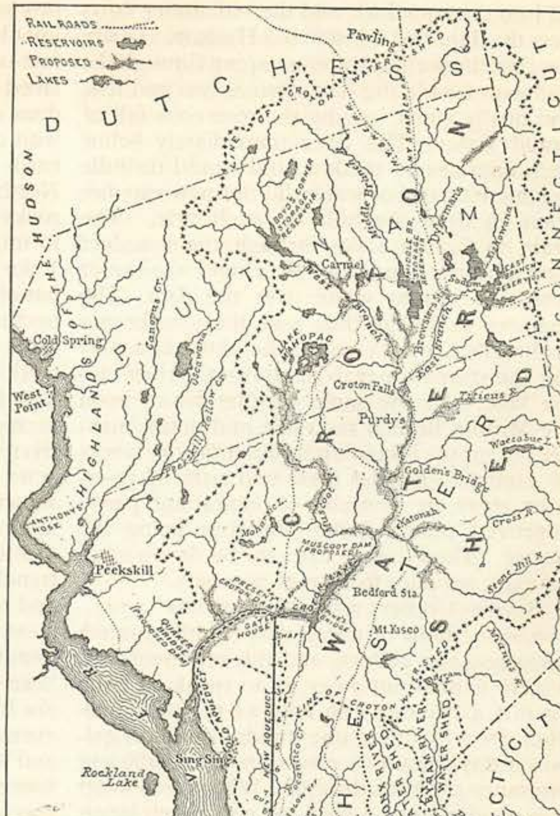
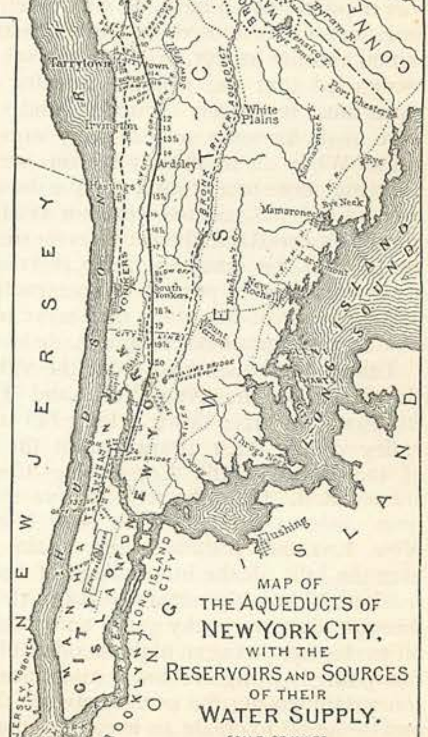
The Croton Valley is distinctively a dairy country. The underlying rock is a micaceous gneiss of remarkably uniform character. This rock is greatly broken up on the surface and appears in steep, irregular hills scattered about in great confusion. Glacial action in the past is plainly marked, and the surface is covered with a thin, gravelly soil, or is bare and stony. Woods formerly completely covered the entire country; but the early settlers cleared off the forests, and to-day there is a second growth of woods covering the steeper and rougher hills. The cleared lands are almost exclusively pasturage and hay-fields, and only a portion of the soil is available for crops. In the southern and eastern parts of the water-shed the few towns are scattered along the main stream of the Croton, for the sake of the water power. Towards the north and west the population is more scattered, and the hills rise to wild and deeply wooded mountains. In point of fact the water-shed is a part of the Highlands of the Hudson, the center being directly opposite West Point, and the mountains are, as it were, foothills of the great Appalachian backbone of the Atlantic seaboard. These stony hills and sloping pastures, these woods and fields, make the great roof on which the rains and snows deposit their pure waters that New York be not athirst. So far as nature is concerned, it is as good and sweet a place to collect water as may be found in the world. If there be any injury to the water, it must come from known and preventable artificial sources. The gneiss rock is practically watertight, and all the water that falls is saved, less the amount that is lost by evaporation. The soil that covers the surface is a filter to restrain any natural impurities that may contaminate the rain or snow. The grass, trees, and vegetation serve as a sponge to hold the water after every rain and let it escape slowly and evenly into the streams. The only possible contamination that can come to the water collected on such a surface must come from the habitations of men and animals. Twenty-five years ago the population of the Croton Valley was very small, and the actual contamination of the water was so small that it was hardly worthy of notice. The ordinary waste of a farm, manure, etc., spread upon grass or plowed land, can do no harm, because the pure, sweet soil and the air are disinfectants and purifiers.

Within the last few years a third railroad has been built across the Croton water-shed, the towns have rapidly increased in size, a large number of summer hotels and boarding-houses have been built, and manufactories have multiplied. From all these may come contaminations. The population of this valley are plain folks, quite as selfish, quite as indifferent to sanitary laws, and quite as firm in their belief in their right to do as seems to them fit, as the rest of us. The Croton gives them water power, its bed is a good place to deposit refuse. Why, they doubtless say, why not use it for water power and a sewer? From the piazza of a farm-house it is difficult to sympathize with a tenement house. A number of committees and commissions have from time to time inspected the Croton water-shed with the view of ascertaining the possible and probable injury to the water that may arise from the neglect or carelessness of the people living there. The last investigation was made by the State Board of Health in 1887, and from their report and from other sources it is evident that the danger from contamination is rapidly increasing. In the opinion of experts the danger is not yet serious. The point is that it grows, and grows rapidly. So evident is this danger that laws have been passed to police the entire district. It therefore depends wholly upon the officers appointed to conserve the water-shed whether we drink in the future pure water or impure water. Had the citizens of New York any real faith in the persons whose duty it is to care for the cleanliness of our big drinking-cup they might rest in peace. Unfortunately so long as they permit certain "private clubs" to decide who shall hold public office that faith must be at least a trifle unstable.

The annual rainfall in the Croton River, as recorded at Boyd's Corner from 1870 to 1886, ranged from 38.52 inches in 1880 to 55.20 inches in 1882. These were the dryest and the most rainy years, and were exceptional, the average being 45.97 inches. This, in a water-shed of about 360 square miles, is ample for a much larger city than New York for a generation to come. There is, of course, a large percentage of loss by evaporation from the surface of the reservoirs and from the ground, yet there should be gathered here sufficient water, provided it is all properly managed, for several generations to come, and enough to form the larger source of supply for a century or longer. There is water enough and to spare. The question is how to economize it, a problem some of the ablest hydraulic engineers in the world have done much to solve.

The rainfall is never evenly distributed through a year, or even through a series of years, and while the average rainfall may be sufficient, the actual supply will be so irregular as to be wasteful and even dangerous. The engineers who have at different times been in charge of the public works of New York have recognized for a long time that the entire rainfall must be conserved. The restraining influence of the woods and ponds must be extended by artificial means. The abundant rains of winter must be saved for use in the dry season of midsummer. Two plans have been proposed. One is to construct, at intervals along the upper waters of the Croton, a large number of artificial ponds or reservoirs, by erecting dams across the streams and impounding the water. Another plan is to erect one large and several smaller dams on the lower parts of the main streams, and thus to collect and store virtually all the water falling into the entire basin. The first of the plans, that of having a series of small storage reservoirs, has already been carried out in a limited way, and is now being extended. The second plan is still under advisement, and will, no doubt, ultimately be carried out, thus combining the two plans. The peculiar character of the country in the Croton basin makes it comparatively easy to construct artificial storage reservoirs, and two have already been built. The first of these, at Boyd's Corner, is on the upper waters of West Branch in the northwest corner of the basin, among the wildest and highest mountains of the district. The second is on the Middle Branch of the Croton near the center of the watershed, between the villages of Carmel and Brewster's. Croton Lake is too shallow to be regarded as a storage reservoir, for its chief duty is to lift the water of the main stream to a level with the mouth of the old aqueduct.

The plan on which this system of reservoirs is operated is very simple. In wet weather the water in the two reservoirs flows away through the "spillways" or waste weirs beside the dams, and runs down the river into Croton Lake. Here a portion of the water is drawn

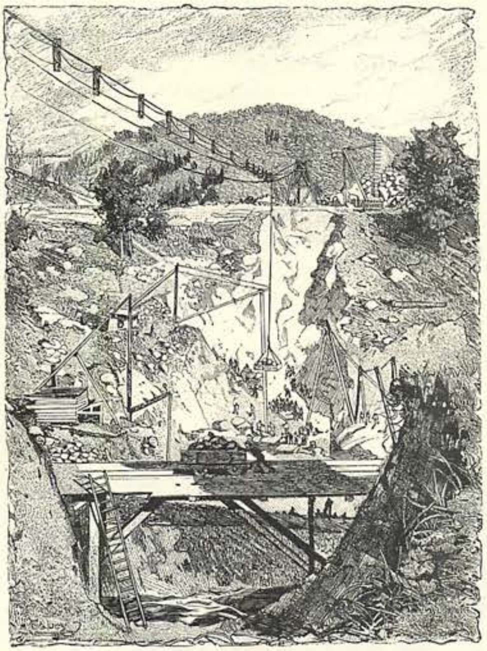
MAP OF THE AQUEDUCTS OF NEW YORK CITY, WITH THE RESERVOIRS AND SOURCES OF THEIR WATER SUPPLY.

off into the aqueduct, and the remainder flows over the dam and is lost in the Hudson. In dry weather the surplus water escaping through the spillways beside the dams grows less and less, and finally stops, leaving the reservoirs full of stored water. The river immediately below each dam ceases to flow, and would dwindle to a mere thread of water did not new supplies come in from the hills on each side. The drain on Croton Lake through the aqueduct soon absorbs the entire flow, and the water ceases to run to waste over the dam. The engineer in charge then asks the gate-keeper at Boyd's Corner to open the gates and permit the stored water to run down the river into the lake. In the same way he draws upon the Middle Branch reservoir, and in this manner the supply is kept up through the dry weeks of summer. Besides these two artificial reservoirs, there are a number of natural and partly improved ponds, Lake Mahopac being the largest. These ponds can also be drawn upon for extra supplies in case of necessity.

Boyd's Corner reservoir contains 2,727,000,000 gallons of water, and Middle Branch 4,004,000,000 gallons, and this represents our reserve capital put away, so to speak, in bank against a dry day. So long as the old aqueduct drew less than one hundred million gallons a day these two reservoirs were sufficient insurance against a drought. When more water was required and a new and very much larger aqueduct was proposed the entire question assumed another aspect. As early as 1858 it was recognized that the storage capacity of the basin must be largely increased, and surveys were made for some new and very large reservoirs. While all of these reservoirs were not built, and more recent surveys have shown that some of the sites selected were not available, it may be observed that the necessity for such storage lakes has become imperative, and three reservoirs are now in process of construction. A passing study of this work may serve to show how a great storage reservoir is made and used.

Taking the town road from the village of Brewster's on the New York and Harlem Railroad, we drive down a long hill into the valley of the East Branch until the works of the Borden Milk Condensing Company are reached. Here the road follows the little river under a bridge of the New York and New England Railroad and again climbs over the hills till the little village of Sodom is reached. There the stream turns to the south through a narrow rocky gorge and then winds off to the east between high, wooded hills. At this point is being erected a magnificent masonry dam closing the portal between the hills and designed to create an irregular lake where now are farms, meadows, and deep woods. The new reservoir will eventually consist of two distinct bodies of water formed by four dams. The first of these dams is of solid rubble masonry faced with dressed granite. To the east of this dam, on the crest of the hill and at right angles with the stone dam, will be a long, low dam of earth and having a heart or core of masonry. North of the dam, on the other side of the rocky hill, are two more earth dams, designed to impound the waters of a little pool called Lake Kishowana and a small brook that flows out of it. Under the hills is to be a tunnel connecting the two reservoirs. The building of the three earth dams is comparatively simple. The work on the stone dam is quite complicated. The first steps were to bore into the hills on each side of the stream and in the bed of the river with diamond drills to ascertain the character of the bed-rock. The borings having shown that the rock is comparatively uniform in character, the river was diverted by means of a temporary crib-work dam, and then a deep trench was blasted out of the bed of the river and out of the steep sides of the hills to form a safe support for the dam. In this trench the foundations of the dam are laid. In the center, near the bottom, large iron pipes with gates are built into the foundations, the pipes being eventually the escape or outlet for the water, and while the dam is being built they serve as a waste weir or outlet for the river. The dam is 500 feet long, 53 feet wide at the base, 12 feet wide at the top, and 78 feet high. The earth dam is 700 feet long, and there will be a roadway on the top of each dam with a turning-place at the end. When finished it will be a magnificent drive, with the broad lake on one side, the deep, rocky valley on the other, with its white fountains below and the wide spillway at the end of the dam, where the surplus water will pour in an enormous waterfall down the rocky face of the cliff. The present hill, where stands the white church, will be like an isthmus between the two reservoirs, the tunnel to connect the two being directly under the crest of the hill. The accompanying pictures give one an excellent idea of the character of the country above the dam, and show the work in operation just as the walls of the great stone dam began to rise above the massive foundations sunk in the hills. The first two illustrations show the deep trench cut in the hills as a foundation for the dam, and the cable hoist used in handling stone. The third picture gives an idea of the character of the country to be eventually submerged.

It is a curious commentary on the demands of modern civilization to observe the effect of building this dam. The million people in the city need a reserve of drinking water, and twenty-one families must move out of their

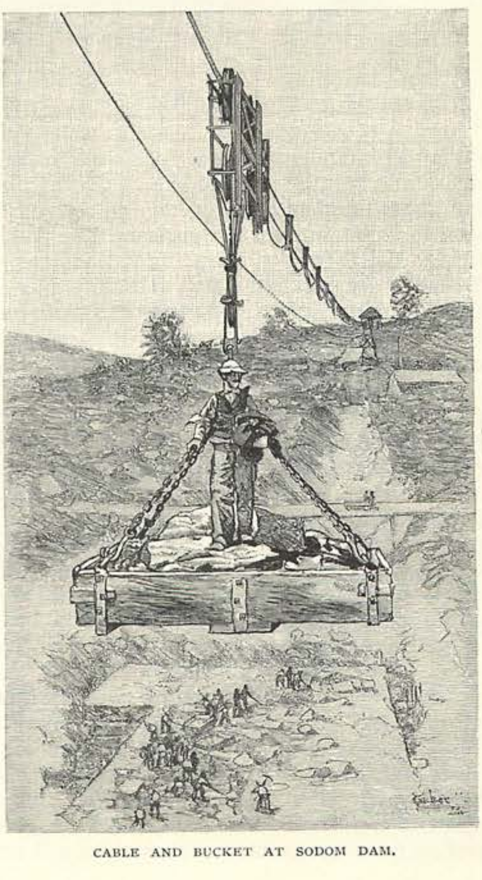


EXCAVATION FOR SODOM DAM.

quiet rural homes and see their hearths sink deep under water. The entire area to be taken for the reservoir is 1471 acres. Twenty-one dwellings, three saw and grist mills, a sash and blind factory, and a carriage factory must be torn down and removed. A mile and a quarter of railroad track must be relaid, and six miles of country roads must be abandoned. A road twenty-three miles long will extend around the two lakes, and a border or "safety margin" three hundred feet wide will be cleared all around the edge to prevent any contamination of the water. This safety border will include a carriage road, and all the rest will be laid down to grass. As the dam rises, the water will spread wider and wider over fields, farms, and roads. Every tree will be cut down and carried away. Every building will be carted off, and the cellars burned out and filled with clean soil to prevent any possibility of injury to the water. Fortunately there is no cemetery within the limits of the land taken for the reservoir. Had there been one it would have been completely removed before the water should cover the ground. Fifty-eight persons and corporations, holding one hundred and eleven parcels of land, will be dispossessed in order to clear the land for the two lakes and the dams, roads, and safety borders.

This East Branch reservoir will give the city two good-sized additional storage reservoirs, and while they will add considerably to the present supply, they will not meet the wants of the city in a year of drought. The Croton water-shed is not yet by any means exhausted, and as fast as needed more of these storage reservoirs will be provided at different places. One will probably be placed near Purdy's, on the little Titicus River. An excellent site for the dam has already been found where the stream passes through a narrow, rocky gorge. A dam will here flow a very large tract of fine farming country to the east and give another sweet, clean drinking-cup for the city. Still others are under consideration near Carmel, and above Croton Lake on Muscoot River.

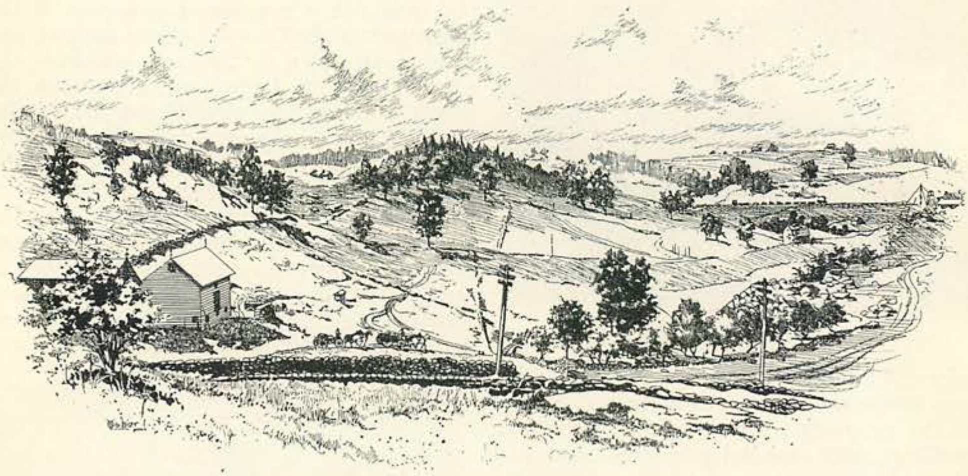
In addition to this plan of storing the surplus water in a number of reservoirs at the upper part of the Croton basin is the proposal to erect, far down on the main stream of the Croton, one very large dam, which with the others will impound virtually all the rainfall of the Croton basin and save thousands of millions of gallons that are now lost. This proposed dam is to be placed within one or two miles of Quaker Bridge. If built it is to be the largest dam in the world, and will impound more than thirty thousand million gallons of water. The lake will be on an average 3000 feet wide and 72,000 feet long, with an average depth of over 30 feet. The dam will add



CABLE AND BUCKET AT SODOM DAM.

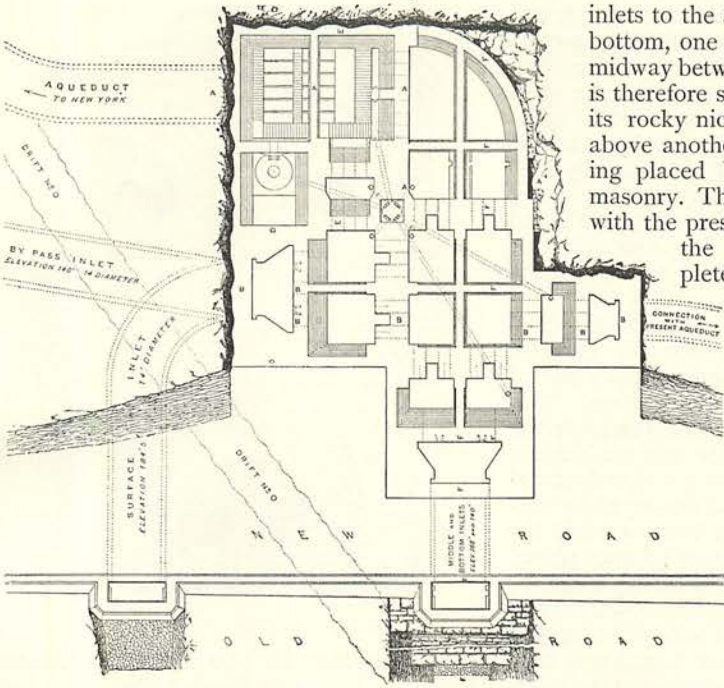
115 square miles to the now available water-shed, and save about all the water now lost on this great surface. Very much has been written both for and against this great dam, but the consensus of opinion appears to be in favor of its erection. That it can be built is beyond discussion. It can also be built with entire safety, both in a sanitary sense as a storage place for water, and in a mechanical sense as a structure absolutely safe against overthrow by floods. The key to the safety of any dam is found in the spillway. Given a good design, good materials, and good work, a dam may be as secure as any structure that can be built. Its life therefore depends on the provision for relieving extra pressure. The water behind the dam rises as the rainfall increases. Before it can reach the top and flow over it finds an outlet in the spillway and runs harmlessly away. It is believed that American engineers are in the front rank of their profession, and modern science places in their hands the exact data of rainfall, water pressure, and strength of materials. It becomes, therefore, only common sense dealing with large figures; and this dam, great as it may seem on paper, is within the ability of our engineers, and its construction and maintenance are within "the limits of safety." The smaller reservoirs will not be useless when the large dam is built, and all these proposed small dams should be built as well as the greater work. It will take five years to build the big dam. Each of the smaller dams can be built in two or three years, and New York cannot go on another year without more water. True wisdom suggests both plans, the smaller reservoirs on the head waters, the larger lake below. Both systems can be used together and be controlled from one point, and then there will not be, for a generation at least, any danger of a water famine, even should two dry years like 1880 follow each other.

When it was first proposed to build a new aqueduct to bring down more water from the Croton water-shed it was suggested that the new and larger dam should be built at once and that the aqueduct should start at the great dam. It was also suggested that the aqueduct should start just above the old dam at Croton Lake. The points in favor of this last plan were these: The water could be let into the aqueduct as soon as completed and without waiting for the new dam. If it were afterwards decided to build the great dam and submerge the present dam, the water could be just as well taken there as at the dam itself. If the dam were built a part of the old aqueduct would be submerged, and it could be used as a supply pipe for conveying the water back from the new dam to the new aqueduct. The old aqueduct could also be connected with the new reservoir at or near the new dam, tapping the river several miles below the present inlet. This plan, therefore, seemed the best, and the new aqueduct was laid out along a line beginning at a point just below Croton Dam.



A FUTURE LAKE AND ISLANDS AT BREWSTER'S.

The Croton Valley at the foot of Croton Lake is very narrow and the stream is walled in by steep, rocky hills. This very fact led to the erection of the present dam at this place. The old aqueduct is on the south bank and follows the line of the country road close under the steep cliffs that line the shore. The new aqueduct would require a gate-house, and, as there was no room on the bank without interfering with the old aqueduct, it was decided to blast out an excavation directly in the side of the hill. This excavation, like an enormous scar on the side of the hill, made the first important



GENERAL PLAN OF THE NEW GATE-HOUSE.

step in the great work of moving the rainfall of the Croton basin into New York. The aqueduct itself begins just opposite the iron bridge, seventy feet below the ground and below the bed of Croton River.

The most simple way to connect an aqueduct with its reservoir, or source of supply, is to place the end of the aqueduct below the level of the water and to put a gate in the conduit to control the inflow of water. This was the plan followed in the old aqueduct. The latest science leads to grave doubts whether this is the best way. Water stored in a reservoir is in different temperatures and in different conditions at different depths. It may be warm near the surface and cool below. It may contain minute forms of life near the surface and be barren below. The engineer should therefore be able to draw the water from different points according to the season and according to the temperature and condition of the water. It is evidently better to let the cold bottom water flow into the city in summer than the tepid surface water. A gate-house is necessary in any event, and in planning the gate-house for the new aqueduct provision was made for the future control over the selection of the water to be sent to New York.

Very soon the great dam must be built. When it is built the water will rise forty feet above the present dam, and the lake opposite the new gate-house will be deep enough to give three inlets to the aqueduct — one near the bottom, one near the surface, and one midway between. The new gate-house is therefore set high up on the bank in its rocky niche with three inlets one above another, the building itself being placed behind a massive wall of masonry. The middle inlet is on a level with the present road on the bank, and the bottom inlet, when completed, will pass directly under the old aqueduct, and will be many feet under the present surface of the lake. All this is, of course, provisional and for the future. For immediate use there is a fourth, temporary, inlet, called the "by-pass inlet," that takes the water from the lake a few hundred feet above the dam. This inlet is the only one that can be used at present, and we must take the water, as we do now, from a point near the surface of the old Croton Lake. Another point with respect to the future had also to be considered. The old aqueduct passes in front of the new gate-house, and by connecting it with the gate-house the water for the old aqueduct could be controlled from the new gate-house and the old gate-house could be given up.

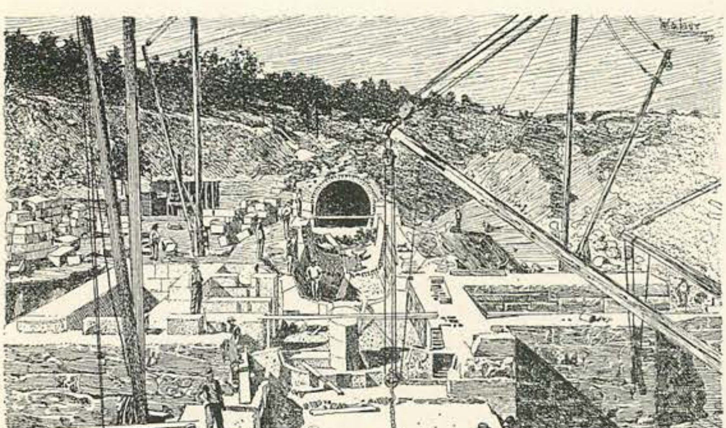
The new gate-house must be regarded as a masterly piece of engineering, both in design and in construction. It is a nearly square structure, built of granite and brick and divided into a number of compartments or vaults. The aqueduct being below the level of the river, it will be impossible to permit the water to rush directly into it under pressure. The aqueduct is here a "flowing conduit." That is, the water does not fill it, but occupies only about four-fifths of the tunnel and flows easily along like an underground river. The water enters the gate-house through the by-pass under pressure, and to relieve this pressure and permit the water to escape into the aqueduct with only its natural pressure or weight it is passed through a series of reducing chambers until its force is spent and it is ready to start easily and slowly on its long, dark journey to the sea. This grand gate-house gives us the key to the whole great engineering work before us.

Walking over the iron floor of the immense room within we may before long peer down into the deep black caves where the great waters are to flow. Here the engineer may guide a whole river under the hills, selecting, mixing, and controlling from day to day the water sweeping with ceaseless roar through the caverns below. Looking down into one of the great vaults of the gate-house the portal of the aqueduct can be seen. It is like the entrance of a cave under the hills. It seems hardly possible that this black archway, so deep under ground, is the direct road to New York, and that the water will easily flow away into the blackness on its long journey to the Central Park reservoir.

FRONT ELEVATION OF BLOW-OFF.

When it was proposed to build a second aqueduct two plans were suggested. One was to parallel the present aqueduct with a second one placed on or near the surface. Two serious objections were found to this route. If the aqueduct were placed so near the Hudson it would interfere with the old aqueduct and could be easily shelled and destroyed by hostile ships that might force their way into the Hudson, or even be destroyed by guns placed on the New Jersey shore, and the city would be without water and at the mercy of the enemy. Some such route must be taken if a surface aqueduct be built; and even were it safe from attack from the river the very fact of the aqueduct being on the surface would always be a menace, as it could be easily destroyed by a mob. Common sense and military prudence plainly pointed to a tunnel placed deep under ground out of reach and easily guarded at the few points where it might come to the surface. Besides this, land owners are content to accept a very small fee for right of way if the tunnel is a hundred feet under their houses and the inconvenience of surface operations is avoided.

These considerations led to the construction of the new aqueduct in the form of a continuous tunnel extending from Croton Dam to High Bridge. The path of the aqueduct is a perfectly straight line from the gate-house to a point just west of Tarrytown Heights and north of Sleepy Hollow. It then turns slightly to the east, passes under the hills, and enters the valley of the Saw-mill River. It then passes, with an occasional slight turn to right or left, directly to the great siphon where the water is to pass under the Harlem River. Reaching Manhattan Island near 180th street, it follows Tenth Avenue to the new gate-house at 135th street, where the aqueduct will end and the pipe lines begin. The pipe lines will then convey the water to Central Park reservoir and to other points for distribution through the upper part of the island. For the entire distance from Croton Lake to 135th street the aqueduct is built of solid brickwork and masonry, reënforced in places with wood and iron, and all, except at three points covering a few thousand feet, is sunk to an average depth of 170 feet and underground. The aqueduct itself is divided into two portions, each part being of different size and shape. The larger part, extending from the lake to a point near the city line, is a horseshoe section and is a flowing conduit; that is, the tunnel is filled to about four-fifths of its capacity. The other portion, extending from the city line to 135th street, is smaller and of

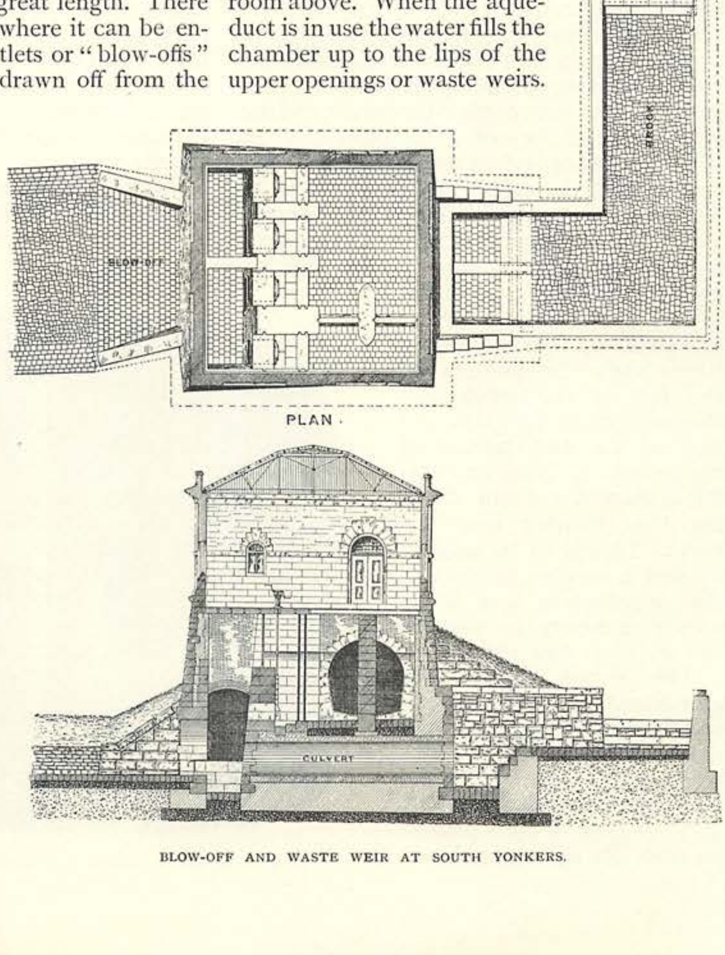


BUILDING THE FOUNDATION OF A GATE-HOUSE AT SOUTH YONKERS.

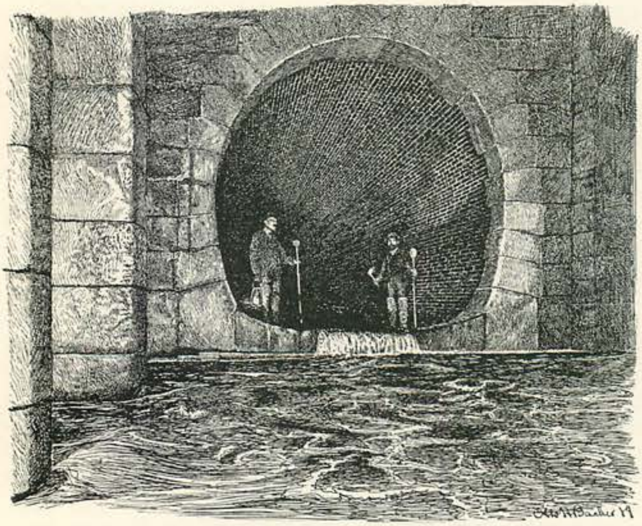
a circular section, and here the water fills the entire tunnel and is under pressure.

In planning an aqueduct two things have to be considered. There must be arrangements made for the steady filling or supply of the aqueduct and for the safe conveyance of the water without contamination and without loss. There must also be provision for shutting off the supply and emptying the aqueduct in order to clean or repair it. We have seen how the new aqueduct is to be supplied from Croton Lake, and its ability to carry the water without harm or loss can be studied as we travel along its route. The fact that the aqueduct is deep underground insures the safety and purity of the water. The next problem was more serious, and involved a long and thorough preliminary study of the country through which the aqueduct passes. A pipe placed deep underground and full of water is difficult of access if at any time it becomes necessary to clean or repair it. If it be of a uniformly descending grade it is possible to empty it by shutting off the supply of water. The water will gradually run out, and the tunnel can then be entered from either end. In the case of the new aqueduct this would hardly be practicable, because of its great length. There must be numerous places where it can be entered, and a number of outlets or "blow-offs" where the water can be drawn off from the whole or a part of the tunnel. There must also be waste weirs for the escape of surplus water, and for maintaining the flowing water at a uniform height in the aqueduct. The actual problem in the case of the new aqueduct was even more difficult, because it was necessary to make at two points sunken loops or inverted siphons. The first of these was made to avoid a swamp, by diving under it, and the second and deeper siphon is under the Harlem River. In emptying the aqueduct the water would lodge in these low places and provision must be made for lifting it out. At other points advantage was taken of the contour of the country, and outlets or "blow-offs" were placed in low valleys, where the water could be allowed to flow away into neighboring streams.

A study of the gate-house and blow-off at South Yonkers will give a general idea of the plan on which these outlets are arranged. Here the aqueduct appears at the south side of a hill and is then built for a short distance in an open cut. As the land falls the aqueduct comes to the surface and is built on the ground and covered with an embankment. At this point a small brook is diverted from its old bed and passes, through stone culverts, directly under a massive granite gate-house. The gate-house consists of a large chamber on the line of the aqueduct and of the superstructure or building (one room) overhead where the gates are controlled. This chamber is built of massive blocks of granite and is divided into two parts by a cross wall or partition parallel with the aqueduct. In this partition are eight openings, four being placed at the bottom on a level with the floor of the chamber, and four placed about ten feet above the first. All of these openings lead directly into the culvert below. The four lower openings can be closed by gates controlled by shafting from the room above. When the aqueduct is in use the water fills the chamber up to the lips of the upper openings or waste weirs.



BLOW-OFF AND WASTE WEIR AT SOUTH YONKERS.



BLOW-OFF AT SOUTH YONKERS, LOOKING NORTH.

had been laid, also the floor of the chamber, the gates, and the lower part of the central column. A portion of the aqueduct is seen to the north just as it emerges from the hill.

The accompanying pictures from photographs in the gate-house reveal the massive character of the stone-work, and also give an impression of the comparative size and shape of the aqueduct at this point. One of these pictures gives a view from the chamber looking north into the aqueduct. Another is from a photograph taken within the aqueduct and looking south across the chamber into the south portal of the aqueduct, and showing the massive walls of the gate-house and the dividing column in the center of the chamber. The picture on the opposite page shows the partition with the gate openings below and the waste weir above. At the left the arch shown in the other picture appears at the lower part of the gate, daylight showing under the crown of the arch. The elevation of the gate-house, on page 212, shows its position on the embankment, and also the openings of the culvert where the brook passes under the aqueduct.

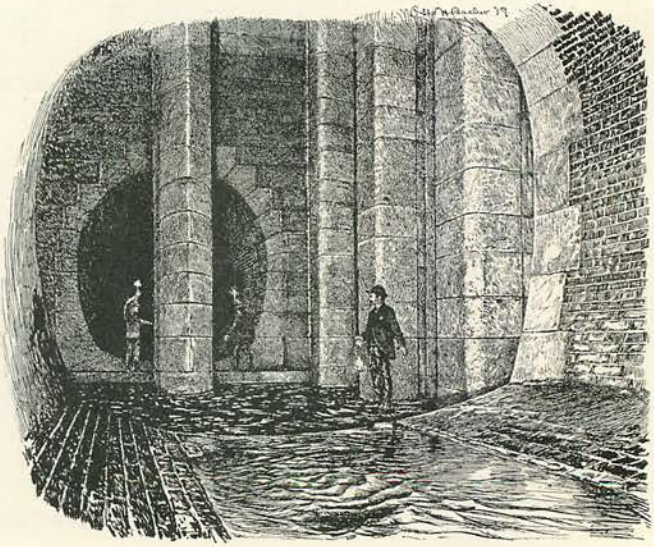
These waste weirs are provided with channels or grooves cut in the stone-work, and by sliding planks into these grooves and thus forming a wooden dam, the height of the water in the aqueduct can be maintained at any point desired.

If at any time it is required to empty the aqueduct or to shut the water off below this point, the gates can be opened and the entire contents will sweep out into the culvert and then into the brook. As soon as the gates are closed the water will again flow on through the chamber towards the city. In the same way the water may be turned aside at Ardsley or at Pocantico, or be shut off at the lake and allowed to escape at any of these points until the aqueduct is empty.

The plan and section and elevation on the preceding pages show the position of the bed of the brook and the positions of the gates, and also of the two portals of the aqueduct. Near one portal is seen a column dividing the chamber into two parts. This is to be used to support a wooden dam across the aqueduct in case it becomes necessary to shut off the water at this point.

The picture showing the gate-house while being constructed will also assist to a correct understanding of the work. The construction had reached a point where the "invert" or floor of the aqueduct on each side of the gate-house

When it had been decided that a new aqueduct should be built in the form of an underground tunnel, careful and elaborate surveys were made of the country to the south of

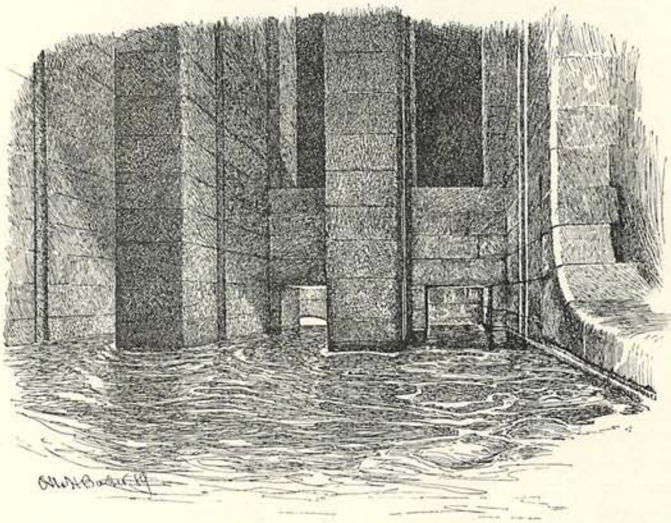


LOOKING SOUTH ACROSS GATE-HOUSE AT SOUTH YONKERS.

Croton Lake to determine the best route. The hills and valleys were searched for the best positions from which to reach the line of the proposed tunnel by means of shafts sunk in the ground. Diamond drills were employed to test the character of the rock in order to find out if it would be sufficiently strong to sustain the roof of the tunnel while the excavations were being made. The cores brought up by the drills showed the bed-rock to be of a generally uniform quality of gneiss with a few belts of limestones, over the entire thirty miles between the lake and a point near 135th street on the west side of the city. Careful studies of all the data collected in the field showed that a tunnel could probably be excavated directly through the rock at an average depth of 170 feet below the surface. The surveys showed that after passing under the high hills to the south of the lake the valley of the little Saw-mill River offered a route to the Harlem that would not require very deep shafts to reach the line of the tunnel. This route would also give two or three points where the tunnel would come to the surface and give opportunities for the building of gate-houses, blow-offs, and waste weirs. From these studies the final plans were made and the drawings and specifications drawn up for the entire work.

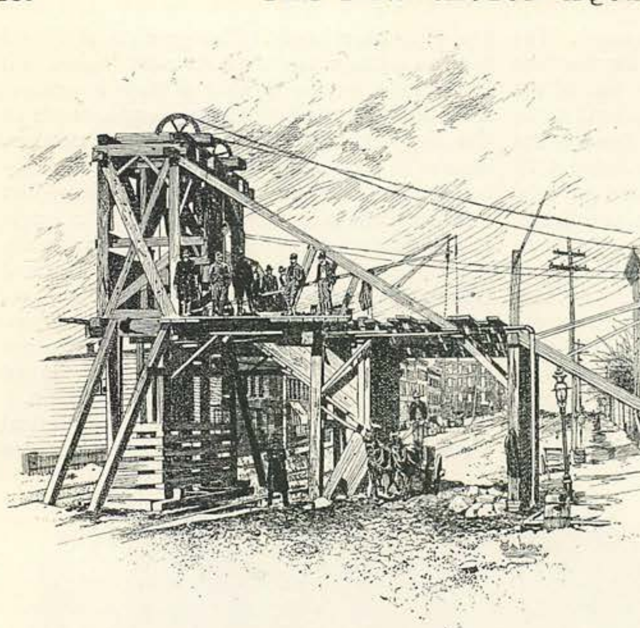
The plans showed that the line of the tunnel could be reached by thirty-two shafts and four open cuts. To gain time, the number of shafts was afterwards increased to thirty-five. For convenience the work was divided into five divisions and these again divided into fifteen sections. The first four sections extended from the lake southward to a point near East Tarrytown and included the open cuts at Pocantico, a distance of about thirteen miles. These sections included the deepest shafts and made the longest portion of the tunnel entirely underground. Sections 5 to 9 inclusive carried the tunnel to the city line and under lower hills, the tunnel twice coming to the surface. Sections 10 and 11 included all the route to the Harlem River, and here the tunnel dropped down deeper under the ground, because if continued on that grade it would have approached too near the surface. Section 12 included the great siphon under Harlem River, and Sections 13 and 14 carried the work to the gate-house at 135th street, where the aqueduct ends and the pipe lines begin. The grade established for the aqueduct was about nine inches' fall in the mile for the flowing portion extending from the lake to a point about a mile south of the city line. The drainage for this portion, in case of repairs, escapes at Pocantico, Ardsley, and South Yonkers. Where the aqueduct changes from a horseshoe section to a circle the tunnel dips deeper into the earth, as already mentioned, and the drainage is into the inverted siphon at the Harlem River, where the water can be pumped out through a blow-off and discharged into the Harlem. South of the river the tunnel gradually rises and the drainage flows north and escapes into the Harlem.

It was estimated that the most economical distance at which a heading could be driven



BLOW-OFF AND WASTE WEIR.

from the bottom of a shaft would be about half a mile, and the next step was to define the positions of the shafts. The selection of the sites was guided in part by this distance of one mile (half a mile each way), in part by the valleys, and in part by convenience in disposing of the "spoil," or waste rock. The bottom of a valley would give the shortest shaft, but leave no room for dump-heaps, and thus all the shafts, while in valleys, were really on the sides of the hills above the bottom or lowest part of the depression to give room for the gigantic heaps of broken stone (spoil) that would gather about the mouths of the shafts. These considerations finally resulted in the selection of thirty-five shafts to be excavated directly into the earth. For convenience the shafts were numbered from 0 to 32, and it is curious to observe the variety of places in which they were started. "Number 0" is a straight drift into the hills from the edge of Croton River below the dam, and the



HEAD-HOUSE OF SHAFT ON TENTH AVENUE.

dump-heaps form a gigantic embankment along the south side of the river. Shafts from Nos. 1 to 17 are either in woods or on farms, some of them being deep in the hills far from any town or village. Shafts 24 and 25 are directly on the banks of the Harlem. Shafts 27 to 30 are placed in the middle of Tenth Avenue, between the tracks of the cable road, and some of them in a thickly built-up neighborhood. The accompanying illustration gives a good idea of the way some of the shafts are placed in the center of Tenth Avenue. The deepest shaft at the great siphon at Harlem River is 419 feet, the deepest among the hills near the lake is 370 feet, and the shortest shaft is only 32 feet.

The actual work of sinking the shafts began about the middle of January, 1884, twenty-four shafts being very soon under way. The first shaft to be excavated to the depth of the top of the tunnel was shaft No. 11A, thirty-one feet deep. Other short shafts were soon after completed and the work of excavating the tunnel was begun. The deepest shaft in the hills, No. 3 (370 feet), was completed in thirty-four weeks from the start, there being five weeks when for various reasons little or no progress was made. The short shafts along Tenth Avenue were not begun until February, 1886, and were completed in from ten to twenty-two weeks. The maximum progress in any one week was forty-two feet in the drift No. 0, and the maximum progress in the vertical shafts was twenty-one feet.

The actual work of driving the tunnel began in shaft No. 11A, in March, 1885, the progress for the first week being forty feet to the north and twenty-four feet to the south. By the 1st of April work was under way in four more shafts, and by May 9 work was in progress in ten shafts. By the 1st of July nineteen shafts had reached the level of the tunnel, and in thirteen of these the tunnel was advanced in one or both directions. The first piece of excavation to be completed was near Shaft 14. It was only fifty-five feet long, and extended to the open cut at Ardsley. The next piece of excavation to be finished extended from Shaft 9 north to Pocantico cut, a distance of 1727 feet. In September, 1886, four more of the drifts either met under ground or had reached an open cut, and in October three more connections had been made, and the tunnel had begun to assume something of its grand proportions. Up to January 1, 1887, a period of ninety-six weeks from the start, the maximum progress in the heading from the shafts or portals (open cuts) had been 84 feet in one week, and the highest average weekly progress in any one heading had been 45 feet. The highest average weekly rate of approach between the headings (south from the shaft, north from the next) was 70 feet, and in many places it ranged from 50 to 60 feet. This was for the time when work was actually going on.

Up to January 1, 1887, the tunnel and open cuts had been excavated for a total distance of twenty-two miles, leaving at that time only eight miles, which were completed in the spring of 1889. The excavation was soon large enough to admit the masons, and work in the tunnel lining began. Parts of the tunnel did not need any interior support, but it was thought best to reënforce it with a brick lining called the "tunnel lining," this brick-work being in turn firmly braced at the sides and roof against the walls of the excavation. The work of making the tunnel lining began in Shaft 9, September 28, 1885. During 1886 the work was under way in one or both directions from a number of shafts, and on the 1st of January, 1887, the side walls of the finished tunnel had advanced 32,382 linear feet, and the "invert," or floor, had been laid for 7722 feet, while the arch, or roof, had been completed for 16,713 feet. The entire brick-work of the tunnel is now completed, and makes a continuous tunnel 29.63 miles long. The total number of bricks exceed 163,000,000, or sufficient to construct thirty-three buildings like the "Tribune" building in New York City.

In this enormous labor at one time ten thousand men were employed, with hundreds of mules and horses and a great number of steam engines, and their labors underground were lighted by scores of electric lights. The mere handling of this vast amount of material involved important questions of transportation. The line of the aqueduct is several miles back from the line of the Hudson, and touches tide-water only at the Harlem River near High Bridge. The only railroad convenient to the line is the New York and Northern, a short, single-track route reaching from the elevated railroad on Eighth Avenue at 155th street to the Croton River basin. Fortunately it has docks on the Harlem, and could load cars with brick and cement from barges and canal boats sent up from the East River. Whenever convenient, materials were sent by this route. For the portions within the city materials were sent by team from points on the Hudson. The enormous mass of broken rock (spoil) taken out in making the excavations involved the purchase of land on which it could be dumped. The material itself is practically valueless, except for filling on town roads or railroads. It has been tried for road surfacing, but is wholly useless, as it soon grinds up to fine powder.

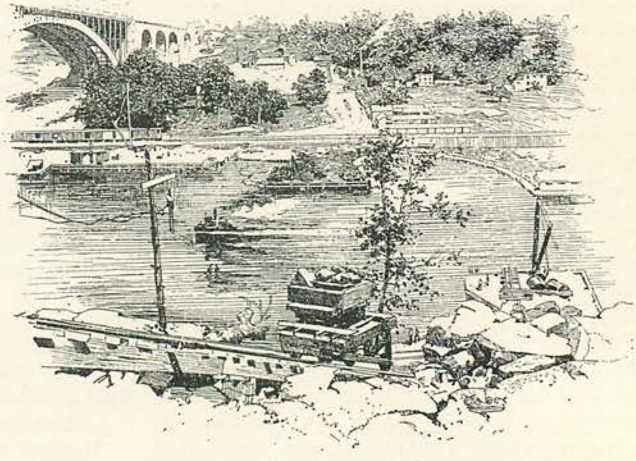
However carefully the plans for such a great engineering work as this are drawn, there must be an element of uncertainty in the actual work. It is impossible to foresee what difficulties may be met deep under the hills. For instance, in sinking Shaft 24, on the east bank of the Harlem, water was encountered in great quantities, so that the work had to be performed under the greatest difficulties. Costly pumping engines were erected and put in operation. Afterwards, when for certain reasons a second shaft had to be sunk still lower, a new position was selected for this shaft not twenty feet away, and this second shaft was as dry as a bone. The diamond drill might have gone a few inches to one side and not have told the exact truth about the rock.

The first serious difficulty was met at a place called Gould's Swamp, in Section 5. The soil proved to be a wet muck overlaying sand with boulders — in fact, a swamp. The only way to avoid this soft spot was to go round it or to pass, deep in the bed-rock, under it. This was finally done, and two shafts were sunk, Nos. 11A and 11B, on the hill-sides on each side of the swamp, and these were connected by a short tunnel, thus forming a bend or inverted siphon.

Another serious difficulty was met at shaft No. 30, near 149th street. Soft, crumbling rock was found that threatened to cause dangerous leakage of water, and it became necessary to line the interior of the tunnel with plates of cast iron. These plates were bolted together to

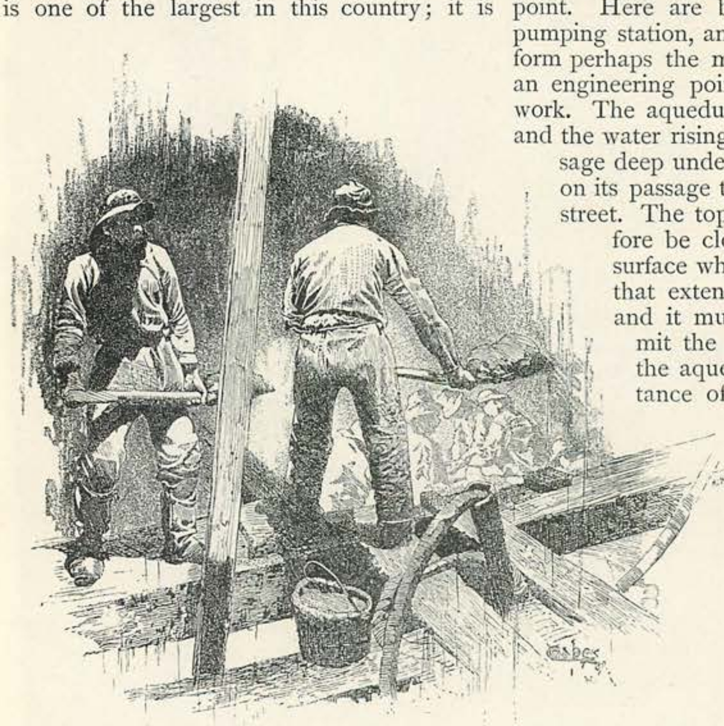
REËNFORCING THE TUNNEL.

form a circular pipe the size of the aqueduct at this point (13 feet 3 inches), and outside of this iron pipe the brick-work was laid as in the other portions of the aqueduct. The illustration on the preceding page shows this work of reënforcing the aqueduct. This iron-lined portion of the aqueduct extends for about 230 feet in the south heading and is about 400 feet south of the shaft.



THE SITE OF THE GREAT SIPHON.

The most serious difficulty met in the entire work was encountered in crossing the Harlem. Two shafts on each bank of the river, Nos. 24 and 25, had been sunk to what seemed to be a proper depth, and headings had been driven east and west across the river where a fissure was met near the west bank of the river, and it was decided to sink the shaft deeper. Shaft No. 25 was continued to a depth of 419 feet; headings were then started, and in due time they met and were lined with brick. The work was not alone one of the greatest difficulty, but it may also be regarded as of the first importance from an engineering point of view. Shaft 25 is one of the largest in this country; it is double, one portion being used for the water and the other for the bucket that is used in lifting the water out of the siphon in case of inspection and repairs. The arrangements for emptying the aqueduct at this point are specially interesting, because not only is the part under the river very deep, but only at this place could a blow-off be arranged for draining that part of the aqueduct south of this point. Here are being built a gate-house, pumping station, and blow-off, and they will form perhaps the most interesting spot, from an engineering point of view, in the entire work. The aqueduct is here under pressure, and the water rising in the shaft after its passage deep under the river must again rise on its passage to the gate-house at 135th street. The top of the shaft must therefore be closed at a point under the surface where it joins the aqueduct that extends along Tenth Avenue, and it must also have gates to permit the escape of all the water in the aqueduct to the south, a distance of two miles. Shaft 26, a few hundred feet from Shaft 25, is arranged with an overflow and blow-off, and it virtually acts as a safety-valve for all that portion of the aqueduct to the south. The overflow here regulates the height of the water in the gate-house at 135th street, two miles south. A short pipe line connects Shaft 26 with the blow-off at the foot of the bluff at



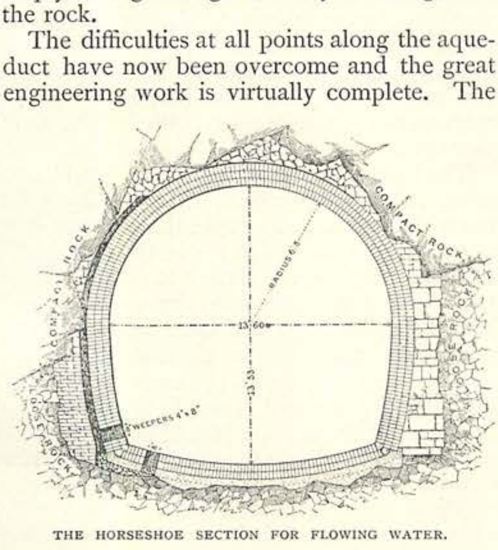
IN SHAFT 25.

Shaft 25. Shaft 24 has also a blow-off for the water to the north as far as South Yonkers.

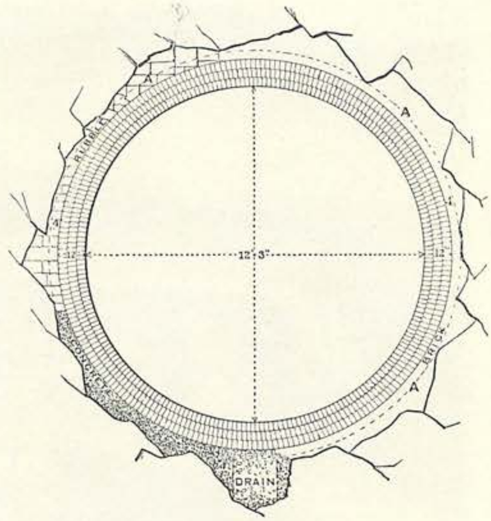
There are, therefore, three grand hydraulic works concentrated within a few hundred feet and in the midst of what promises to be a populous part of the city. Moreover, these works, though partly unseen, are placed between two other great works that testify to the skill of American engineers. To the south is High Bridge, justly famous as a lofty and beautiful stone structure, and to the north is the Washington Bridge. This new bridge is formed of two immense steel arches, the largest single arched spans in the world. The picture on the opposite page gives an idea of the character of the Harlem Valley at this point. The picture gives a view across the river, and shows the head-house and other works at Shaft 24. At the left is seen a portion of the new bridge, and below, on the river banks, are the two landing stages where the brick, cement, and other materials used in the aqueduct were landed. It also gives a view of the inclined railway for bringing brick and stone up from the river to Shaft 25.

In addition to the larger and unexpected difficulties met in building the aqueduct more trouble was looked for in the way of soft, broken, and weak spots in the rock. These were overcome by means of timbering, as in a mine. However, the amount of timbering required was not excessive, only about 39,000 feet of the aqueduct tunnel being supported by timbers outside the brick lining. This timber-work was put in before the bricks were laid, and in some cases was left in position when the lining was put in. Completely inclosed from the air, it will last for a long time; and even if it decays no harm can follow, as the tunnel lining is backed up by masonry and is amply strong enough to carry the weight of the rock.

The difficulties at all points along the aqueduct have now been overcome and the great engineering work is virtually complete. The



THE HORSESHOE SECTION FOR FLOWING WATER.

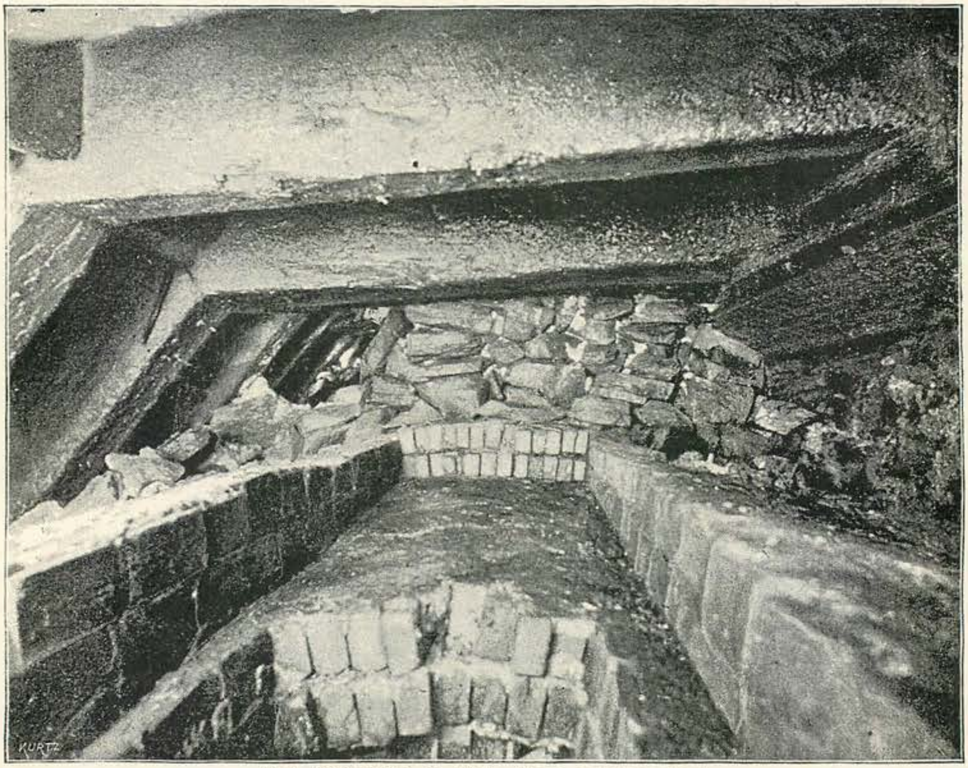


THE CIRCULAR SECTION FOR WATER UNDER PRESSURE.

upper part from the lake to a point near the city line is of a horseshoe section, the interior dimensions being 13.60 feet wide at the top of the side walls and 13.55 feet high in the center. The accompanying section shows the shape of the tunnel lining. The lining consists of three and sometimes four cornices of brick laid in cement. The actual excavation, as shown in the diagrams, is larger than the tunnel lining, and the space between the lining and the sides of the excavation is represented as filled with masonry or with additional brick-work. This exterior work was essential in order to brace the arched lining against the weight of the rock overhead. Without this masonry at the sides and top of the lining the pressure of the rock might crush or distort the brick-work and destroy or seriously obstruct the aqueduct.

The tunnel south of the city line descends deeper underground and is circular in section and smaller in diameter, and will connect with an additional storage reservoir to be built at Jerome Park. The section above gives a good idea of this part of the excavation and of the round tunnel lining. It also shows the masonry backing used to reënforce and protect the lining and assist in carrying the weight of the rock above. The diameter of the circular part of the aqueduct is twelve feet three inches, except under the Harlem River, where it is reduced to ten feet six inches.

Not long ago the writer walked for a mile or more through both the arched and circular portions. Entering by an unfinished portal, left open on account of repairs, the first impression was rather depressing. The ladder was wet with clay, and the sunlight fell upon the curved walls and a wide and rapid brook flowing between



CAVE OVER CROWN OF ARCH. (FROM A PHOTOGRAPH.)

them. A rubber hat, rubber coat, and long rubber boots were awkward but comfortable. There was a cool wind blowing from the two black-arched caves, and it was but a moment's change from bright sunshine to intense darkness, relieved only by the lantern in the hand. The floor had a gentle slope towards the center and for about a foot on each side was comparatively dry. The sense of walking half in a brook and half on its slippery bank was peculiar at first, but in a little while the trick of walking on the edge of the water close to the side wall had been learned.

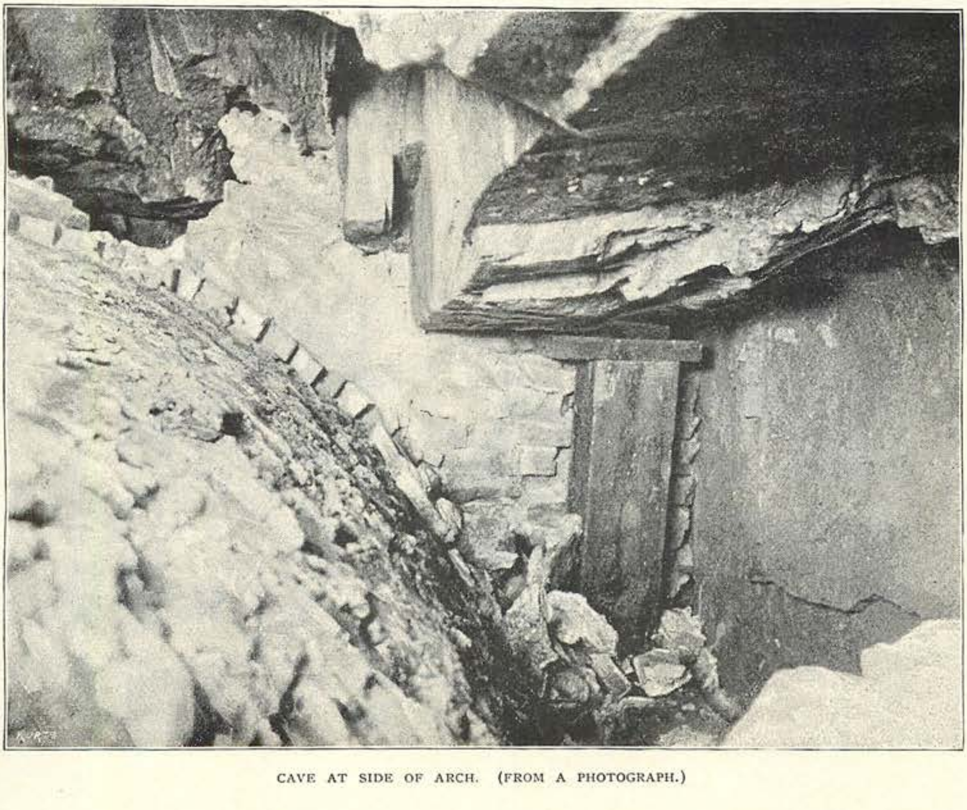
The spot of sunlight behind us faded away to only a yellow star that at last went out. The intense darkness was blacker by contrast with the black walls that here and there in the light of the lamps sparkled with drops of moisture. Occasionally a white mark gleamed with strange distinctness on the walls, showing where the engineers or inspectors had measured the work or left traces for future measurements or inspections. The silence, the cool air gently moving through the tunnel, the narrow circle of light about the lantern, appealed strongly to the imagination. Every splashing footfall echoed strangely, and there seemed at times to be a deep murmur in the air. We paused and listened, but heard nothing save the faint ripple of the water. Then might come a distant sound, or rather reverberation, like the ghost of a thunder peal. Standing in the water in the center of the tunnel and looking either way there was only deep blackness, and it was difficult to decide from which direction came the faint rolling sound. A word spoken seemed to start tremendous echoes, and a note sung loudly floated away and came back again in a long-drawn-out sigh. Several words spoken quickly were repeated distinctly out of the black void beyond the little circle of light. Again we heard the far-away booming, and the engineer said that men were at work perhaps a mile away. We might meet them yet.

The lines of bricks stretch on and on in uniform, unbroken precision. The sloping floor never changes its exact angle, the walls are ever exactly in line, and high above the head is the arched roof. It is the perfection of mechanical work stretching ever onward through darkness. We pass a gate-house and cross its magnificent stone floor, and listen to the roar of the escaping water, and watch the curious effects of light shining upward through the gates and bringing out the massive blocks of granite into startling relief. Again the great arch welcomes to darkness.

Ahead there appears a faint, white cloud, or nebulous spot of light. In a moment we are close to it, and find it some workman's tools covered with white canvas. It is only a hundred feet distant, and yet seems immensely removed. All sense of distance is lost in such deep darkness. Looking up, a circular opening is seen where daylight streams faintly down a shaft, lighting an iron ladder. This is one of the finished shafts, and the light shining on the white canvas spread over the tools at the bottom gave that peculiar nebulous appearance in the gloom. Nearly all the shafts are completely closed, and only a few are left like this—permanently open. The ladder ends in a little house that serves as a protection from the weather and from improper visitors to the tunnel.

As we walk on there are sounds in the air, echoes from yet unseen workmen. Soon through the murky air are seen star-like spots of light. There is a flash from an electric light and we meet piles of brick, stone, and cement. There are voices and a sound of tools and we come to a wooden staging, or "false work," and climb a short ladder and stand close to the roof among a group of workmen. There is a square hole cut in the arched ceiling, and with much scrambling we crawl through and sit down directly on the top of the tunnel lining. The space between the lining and the rock is not high enough to enable one to stand upright, yet high enough for a comfortable seat on the top of the work. The cave-like place extends for some distance in both directions. The candles light up the wet, ragged rocks overhead, some heavy timbers in the distance, and the clean red bricks of the arch.

This space over the tunnel lining is only one of a great number that have been found at different points along the aqueduct. They appear sometimes at the top, sometimes at the sides, sometimes extend completely over the tunnel lining from side to side. In the specifications for the work all these spaces are marked as filled up solid with rubble masonry. The masonry is necessary to the strength of the aqueduct, and it was to be supplied in all cases for the whole length of the tunnel. It was not so supplied in this and in many other places. Moreover, the specifications call for three, and in some cases five, courses of solid brick laid in cement. The upper course in this cave is not laid in cement at all. The bricks on the top of the arch are as clean as on the day they were made. No cement was used, and the bricks were merely laid loosely in place and left there. The hole cut in the arch was made by the engineers to test the work, which was found wanting.

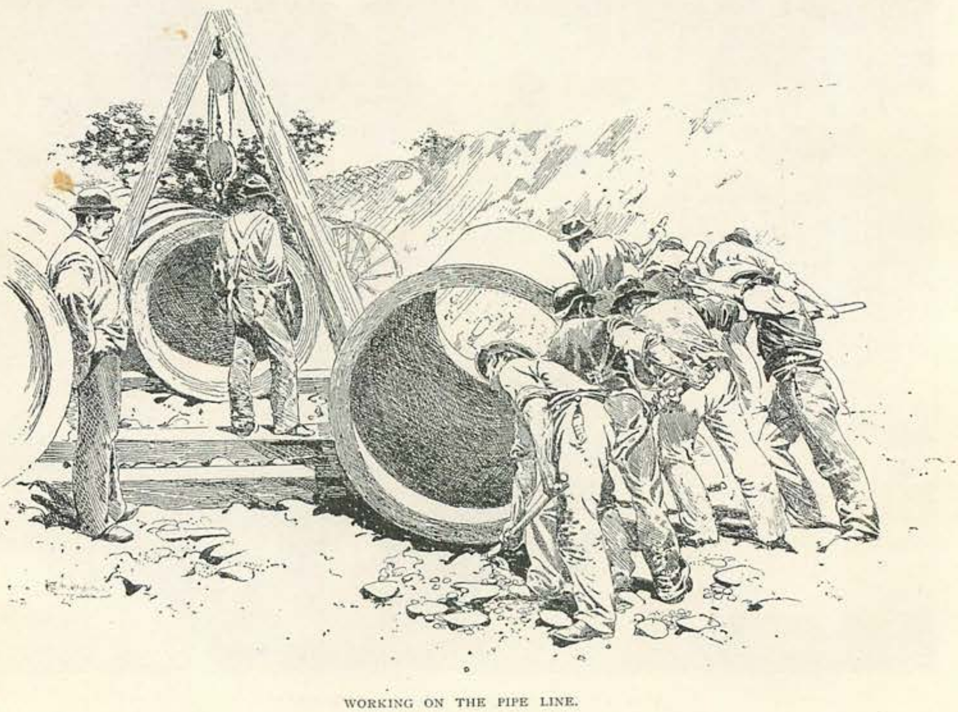


CAVE AT SIDE OF ARCH. (FROM A PHOTOGRAPH.)

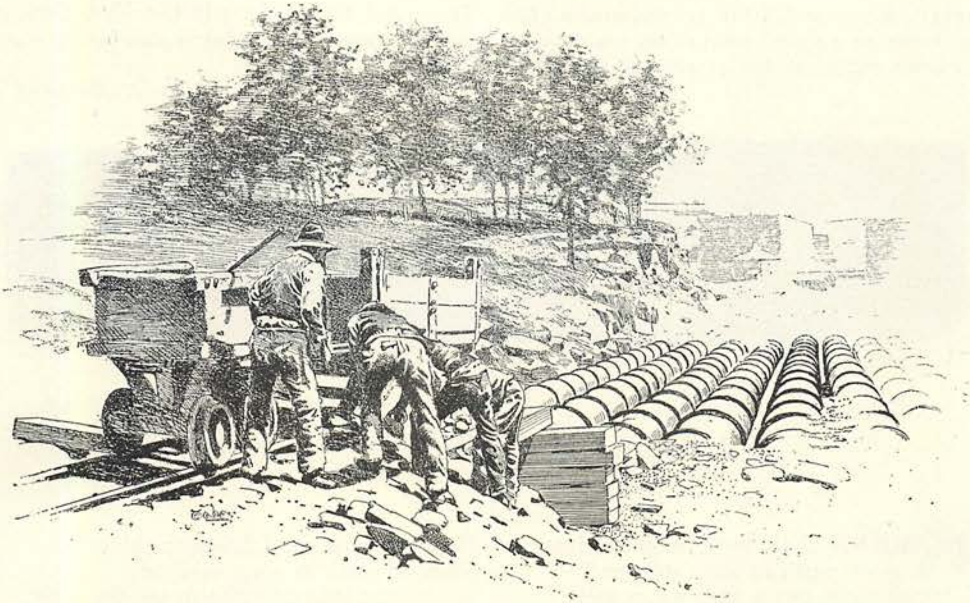
That this statement may not seem exaggerated, two pictures are presented on the preceding pages from photographs taken in two of these caves. In the first the hole cut in the arch is shown with one course of brick properly laid, two courses badly laid, and two courses simply left out. More bad work can also be seen in the other picture. The rock above is the roof of the excavation, and all the empty space represented in the picture was paid for by the citizens of New York at the rate of about five dollars a cubic yard. In some of these caves cross-walls were built to deceive the engineer and lead him to think all the space had been built in solid. In one of the pictures such a cross-wall is shown with a hole knocked in it to show that another cave existed beyond. It is now known that these defects occur in the larger part of the aqueduct, and that over one million dollars were at one time paid out for work that was never performed, and that was certified to have been performed by those appointed to watch the work.

Happily the faults of which these pictures are such unimpeachable witnesses have been repaired, at the expense of the contractors, but they resulted in a complete change in the administration of the work, and the whole business is now but a bad memory. We can only hopefully look forward to the day when "practical politics" shall no longer rule our great public works. The time is fast coming when the selfish greed of political "halls" and the personal necessities of aspirants for public office can no longer thrive on the robbery of the people. Some day the American people will insist that neither governors nor mayors shall appoint public servants at the behest of political managers.

The aqueduct itself ends at the gate-house at 135th street and Tenth Avenue. The water rises through a shaft into the great vaults of the gate-house and then flows through eight lines of huge iron pipes into the city. Four of the lines of pipes lead directly to the reservoirs at Central Park, and four of them branch off at different points to supply the upper and central parts of the city. The laying of these pipes was of itself a great piece of work. The gate-house is a few hundred feet east of Tenth Avenue, and the pipe lines all start from the bottom of the gate-house deep underground. The surface slopes rapidly to the south, and advantage was taken of some partly unoccupied land to lay out a new street extending in a southeast direction from the gate-house to 125th street. This new street, now called Convent Avenue, made a bed for the eight lines of pipes. A trench was cut out the entire width of the street, and in it the pipes were laid. At one or two places the pipes came to the surface, and here the street was raised to cover them. The illustrations on other pages give an idea of the size of these great pipe lines and of the manner in which they were laid. At 124th street gates were put in the pipe lines, and



WORKING ON THE PIPE LINE.



PIPE LINE ON CONVENT AVENUE, FROM GATE-HOUSE.

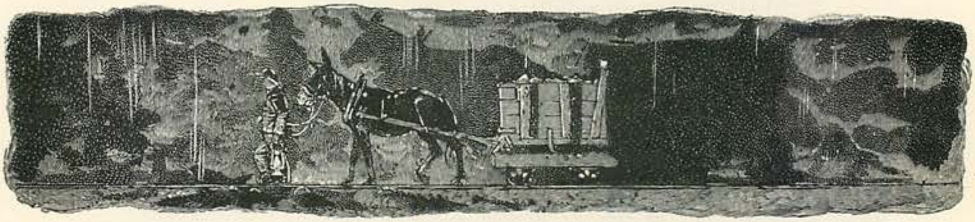
blow-offs were arranged in connection with the sewers. At 125th street the pipe lines begin to branch off, one line turning east along that street. The other lines go on towards the south along the east side of Morningside Park. Other lines diverge at different points, and the four lines for Central Park pass down Eighth Avenue until they enter and cross the park to the old reservoir.

Compared with other tunnels, the new aqueduct is easily at the head of all works of a like character in the world. The cities of Chicago and Cleveland are each supplied with water through tunnels extending out into a lake. The first Chicago tunnel is 5 feet in diameter and 10,567 feet long. The second tunnel is 7 feet in diameter and 31,490 feet long. The Cleveland tunnel is only 5 feet in diameter and 6661 feet long. All of these tunnels were laid in comparatively soft materials. The Baltimore water supply includes a rock tunnel, twelve feet in diameter and seven miles long, and is lined with brick-work for about two miles. The old Roman aqueducts were several of them longer than the Croton Aqueduct, but they were all very small, and were merely masonry conduits a few feet in diameter. The Liverpool water supply is conveyed by an aqueduct about twice as long as the Croton Aqueduct, but it is mainly a surface aqueduct, there being only a little tunnel-work. A portion of the aqueduct is merely a pipe line. The supply is from a reservoir formed like that at Croton or at Sodom, by building a dam across a narrow gorge in a valley among the mountains in Wales. The dam is larger than that at Sodom, being 136 feet high, while that at Sodom is only 78 feet. Compared with the proposed dam it will be small, as the new dam is to be over two hundred feet high, and will be the highest dam in the world. The aqueduct tunnel, when compared with railroad tunnels, is a little smaller in diameter than the three most famous tunnels, but is very much longer. The Hoosac Tunnel is only 24,000 feet long, the Mont Cenis is 8 miles long, and the St. Gothard 9½ miles long, while the new Croton Aqueduct, as we have seen, is nearly 30 miles long.

In conclusion it may be observed that with the new aqueduct completed New York City can draw 318,000,000 gallons of water from Croton Lake. Combined with the old aqueducts it can have on tap, as it were, 415,000,000 gallons every 24 hours. In rainy years like 1888 and 1889 it will be able to use this great supply of water freely.

At the present time we have the Boyd's Corner reservoir, holding 2,700,000,000 gallons, and the Middle Branch reservoir, holding 4,004,000,000 gallons. These, with the 2,000,000,000 in Croton Lake, give a reserve of 8,704,000,000 gallons. The new reservoir at Sodom, now nearly finished, will add 9,000,000,000, and the reservoirs on the Titicus and Muscoot rivers and at Carmel, to be finished within three years, will give 22,000,000,000 gallons; so we are sure next year of 17,704,000,000 gallons, and of 39,704,000,000 two years later. Thus we have to-day a reserve of 17,700,000,000, or enough to last a few months only in a year of drought; but when the large dam is built we shall have 30,000,000,000 gallons more, or a grand total of 69,704,000,000, a reserve sufficient for a series of dry years. Then, and then only, will the New York of the near future be absolutely safe from a water famine.

Charles Barnard.



THREE CHRISTMAS CHIMES.

I.

HEARKEN! how the Christmas chime
Sings on earth its song sublime!
"See those twain with weary feet
Wander through the village street—
Doors are closed against the stranger.
See the Child, the meek and lowly,
Christ, the mighty, the all-holy,
Sleeping cradled in a manger."

Sing your joy, O Christmas chime!
Let us keep the Christmas-time.
Be the loaf of plenty doled,
Be the poor man's heart consoled.
Thus we keep the Christmas-time.

II.

Hearken! still the Christmas chime
Sings on earth its song sublime!
"Wondering shepherds see the night
Flooded with celestial light —
Wondering hear the angel message;
Come, and let us kneel before him,
Let us find him and adore him.
Peace on earth this Child doth presage."

Sing your joy, O Christmas chime!
Let us keep the Christmas-time.
Let all strife and hatred cease,
Kindness live, good-will and peace.
Thus we keep the Christmas-time.

III.

Hearken! still the Christmas chime
Sings on earth its song sublime!
"Eagerly the Magi sped
By the wondrous star-beam led,
Gold and myrrh and incense offer.
He brings most, yes, he the nighest
Draweth unto God the Highest,
Who a heart of love doth proffer."

Sing your joy, O Christmas chime!
Let us keep the Christmas-time;
Love shall be the law to bind
In one band all humankind.
Thus we keep the Christmas-time.

Constantina E. Brooks.