base the slope is 65%. The main dam, a section of which is shown in Plate III, extends across the river channel a length of 552 feet. This is continued by an overflow rollway weir section in masonry 817 feet long, 10 feet lower than the crest of the main dam. The total volume of masonry was 180,000 cubic yards. It is of the class known as cyclopean masonry, composed of large blocks of granite imbedded in a mortar of concrete, comprising about 30% of the mass.

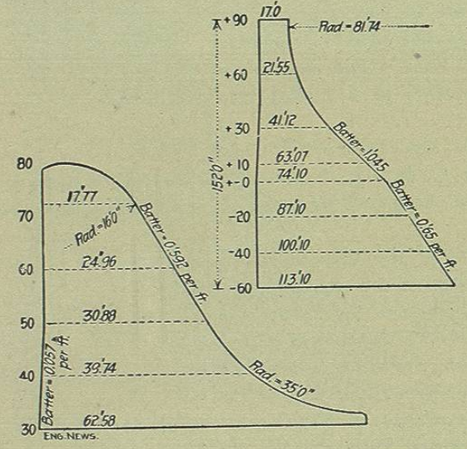

FIG. 221.—SPIER FALLS DAM, N. Y. PROFILES OF OVERFALL AND ABUTMENT SECTIONS.

The dam creates a reservoir 5.5 miles long, from which a power-head of 80 feet is derived, furnishing 20,000 H.P. at the minimum low water.

The dam was built under the supervision of Mr. Charles F. Parsons, chief engineer.

The Ithaca Dam, New York (Figs. 222 and 223).—One of the curiosities of recent dam construction is situated two miles from the city of Ithaca, on Six-Mile Creek, in a narrow rock gorge, with vertical walls but 90 feet apart. The dam was designed by Prof. Gardner S. Williams, M. Am. Soc. C. E., of Cornell University, who was inspired by the narrowness of the site to attempt a structure of most unusual slenderness and peculiar form.

It was intended to be 90 feet in height, with a radius of 57.75 feet on the down-stream face, in the shape of a section of a spherical shell, with overhanging crest. In deference to popular distrust of the safety of the structure, it was finally reduced to the height of 30 feet above

base, and finished off with an up-stream batter of 45° and a top thickness of 1 foot. The maximum thickness is 7.75 feet. The dam is composed of concrete, mixed in the proportion of 1 part cement, 2 parts sand, 2 parts gravel, and 2 parts broken stone, crushed to pass a 4-inch ring. The concrete was placed between thin walls of vitrified paving-brick, laid in a single course on each face, in cement mortar anchored into the body of the concrete by flat steel bolts, $1\frac{1}{2} \times \frac{1}{8} \times 7$ inches, turned up $\frac{1}{2}$ inch at each end and placed at every fifth brick in every fifth course.

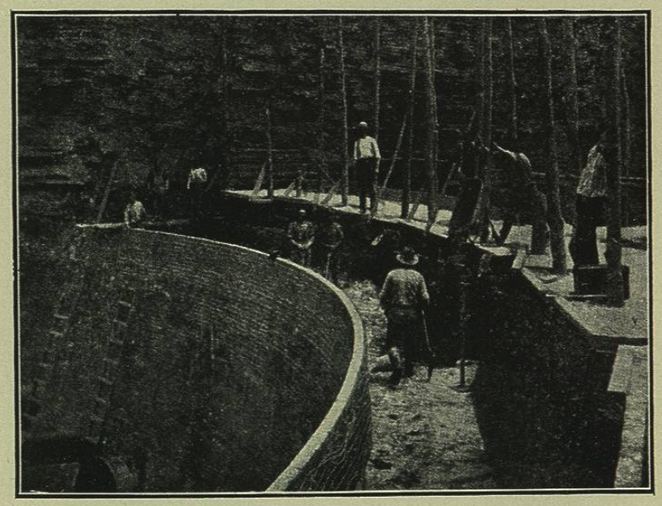

FIG. 222.—ITHACA DAM, NEW YORK, ILLUSTRATING CONCRETE CONSTRUCTION BETWEEN BRICK-FACING FORMS.

Inside the brick facings is a layer of rich cement mortar, 3 inches thick, in which are imbedded bands of steel, 3 inches wide, $\frac{3}{8}$ inch thick, placed 4 feet apart, extending entirely around the structure, and tied through the dam every 4 feet by $\frac{5}{8}$-inch steel rods, having a nut on each side of the bands. Over the steel frame thus formed is a wire netting with 4-inch mesh imbedded in the mortar.

The dam cost $25,000 and required the following quantities: Excavation, 500 cubic yards; concrete, 1000 cubic yards; brick, 120,000 (240 cubic yards); steel, 5000 pounds; cement, 1800 barrels. All concrete was put in very wet. The brick walls were laid flat, 3 to 4 feet in advance of the concrete and obviated the use of other forms.

The structure was built for the Ithaca Water Co. to provide storage for city supply from an area of 48 square miles.

The Ashokan Dam, New York.—The City of Greater New York is engaged in the most costly work ever undertaken by a municipality for the increase of its water-supply to the extent of 500,000,000 gallons daily by the gathering of water in huge reservoirs in the Catskill Moun-tains, to be conveyed by an aqueduct of enormous size, 82

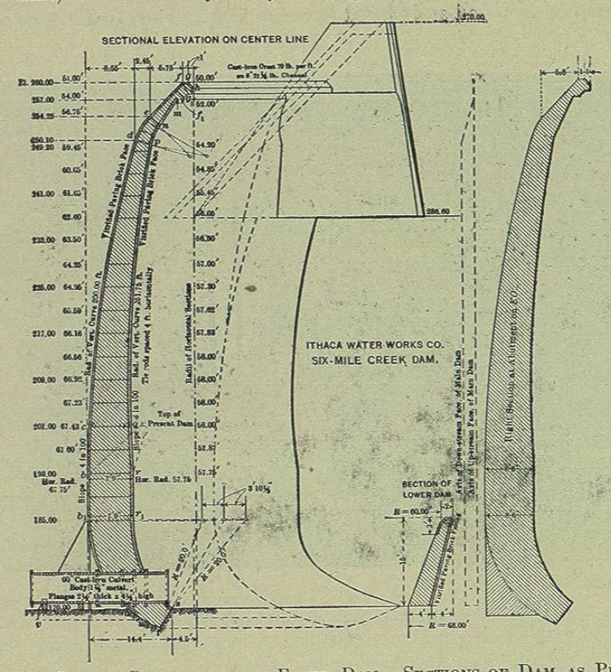

Fig. 223.—Ithaca Concrete-brick Faced Dam. Sections of Dam as Planned.

miles long, to the city. The works are estimated to cost upwards of $162,000,000.

The principal reservoir, called the Ashokan reservoir, will cover an area of 8300 acres, and have a capacity of 368,030 acre-feet. Its maximum depth will be 180 feet, and its mean depth 45 feet, or 25% of the maximum. It will receive its supply from the run-off of 255 square miles of watershed area. A masonry dam to contain 884,000 cubic yards of masonry, called the Olive Bridge dam, is to be erected, and in addition there are required five earth dams or dikes to complete the inclosure of the basin, involving the handling of about 7,000,000 cubic

yards of earth. The excavation required for these structures is enormous in quantity, amounting to 1,910,000 cubic yards of earth, and 425,000 cubic yards of rock. The specifications require all of the work to be completed in eighty-four months.

Bids were received for this work August 6, 1907. The lowest bidder was the John Peirce Company of New York in the aggregate sum of $10,315,350, but the contract was awarded to the next bidders, MacArthur Bros. Co. and Winston & Co., for $12,669,775, on the recom-

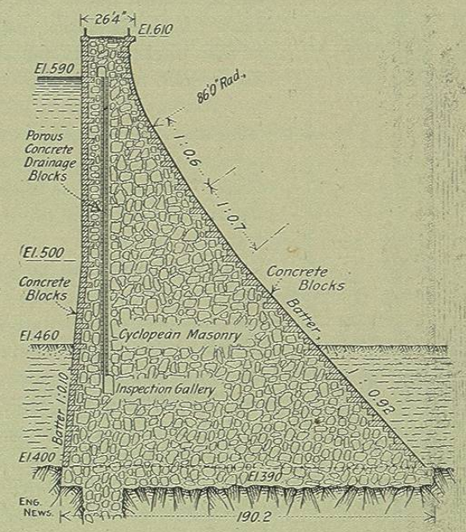

Fig. 224.—Ashokan Dam, Masonry.

mendation of the Chief Engineer, J. Waldo Smith, M. Am. Soc. C. E., and the Board of Consulting Engineers, Messrs. John R. Freeman, Frederic P. Stearns, and Wm. H. Burr, M. M. Am. Soc. C. E., on the ground that the lowest bid was below cost in the earthwork portion. This position is not sustained by a board of nine advisory engineers, who maintain by minute cost analysis that the lowest bid would have been profitable.

The Olive Bridge dam, with crest elevation of 610 feet, will consist of a central masonry structure, 1000 feet long, straight in plan, with an earth dam on the same line, 2100 feet long on the north side, and a south wing of 1540 feet length. These embankments will have concrete core-walls reaching to elevation 596, or 6 feet above the flow line of the reservoir.

The masonry structure will be built of cyclopean rubble masonry between face walls of large concrete blocks, and will have a maximum height of 220 feet, a base of 190.2 feet, and a top width of 23 feet below the coping. It will carry a roadway, for which the top is corbeled out to an extreme width of 26 feet 4 inches.

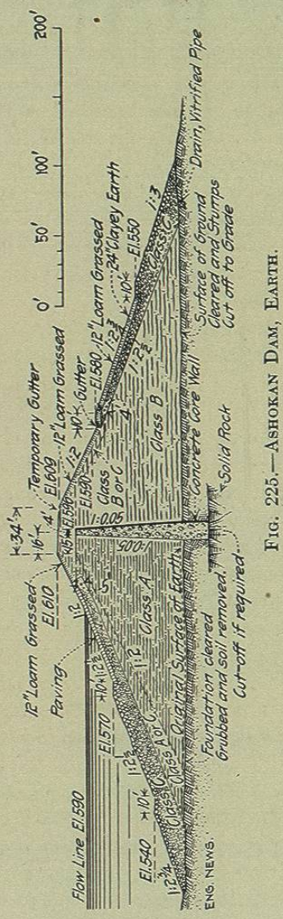

Fig. 225.—Ashokan Dam, Earth.

By this means all possibility of upward pressure upon the base of the dam or any portion above the base through the transmission of pressure by communication seams or cracks or open joints from the reservoir, will be avoided, and any water that may find passage through the face will be intercepted and drained away. The designing engineer was Mr. C. E. Gregory; Mr. Benj. S. Wever is assistant engineer in charge, and Mr. Alfred D. Flinn, department engineer.

The precedent established at the Wachusett reservoir of stripping all surface soil from the basin was not followed in this case, but after investigation was declared to be an unnecessary expense.

The Titicus Dam, New York.—This structure is a part of the system of storage for the supply of New York City, and was built in 1890 to 1895, at a cost of $933,065. It resembles the New Croton Dam in general design, in that it is a combination of masonry and earth, the higher portion in the center of the valley consisting of masonry, flanked on either side by earthen embankments, provided with a central core-wall of masonry. The main

masonry dam is 135 feet high above foundation, 109 feet high above original surface, 75.2 feet thick at the level of the stream-bed, 20.7 feet thick at top, and 534 feet long. The earthen dams are 732 and 253 feet long, respectively, the total length of dam being 1519 feet. A waste-weir, 200 feet long, built in steps on the lower side, is carried over a portion of the main masonry dam. The masonry consists of rough rubble, faced on either side with cut stone, laid in regular courses. The earthen dam is 9 feet higher than the crest of the spillway. It is 30 feet wide on top, with slopes of 2½ to 1. The core-wall is of rubble masonry, 5 feet on top and 17 feet thick at a depth of 98 feet. It reaches to a maximum height of 124 feet above base. The greatest depth of water is 105 feet. The dam was planned by A. Fteley, Chief Engineer, and construction was originally in charge of Charles S. Gowen, who was subsequently succeeded by Alfred Craven as Division Engineer, and M. R. Ridgway, Assistant Engineer.

The Sodom Dam, New York.—This is a purely masonry structure, built across the east branch of the Croton River in 1888–93, by the Aqueduct Commission of New York, and, in connection with the Bog Brook dams 1 and 2, forms what is known as "Double Reservoir I." The reservoirs were connected by a tunnel, 1788 feet long, by which the surplus water from the Sodom dam is made to supply the other reservoir, whose watershed was but 3.5 square miles, while that tributary to the Sodom reservoir was 73.4 square miles. The tunnel thus equalizes the supply from the two watersheds. The combined storage capacity of the two reservoirs is about 9,500,000,000 gallons. The Sodom dam is 500 feet long on top, 98 feet high above foundation, 78 feet above stream-bed, and the masonry has a bottom thickness of 53 feet, and is 12 feet wide at top. It contains 35,887 cubic yards of rubble masonry, chiefly laid in Portland-cement mortar, mixed 2 to 1 and 3 to 1. A continuation of the masonry dam is carried along the crest of the ridge, nearly at right angles to the wall, in the form of an earthen embankment, 9 feet high, 600 feet long. In extension of this bank is a masonry overflow, 8 feet high, 500 feet long.

The cost of the dam was $366,490. It was planned by Chief Engineer Fteley, and constructed by Geo. B. Burbank, Division Engineer, and Walter McCulloh, Assistant, later Division Engineer. An interesting account of the dam is to be found in a paper prepared for the American Society of Civil Engineers in March, 1893, by Mr. McCulloh, from which it appears to be one of the few masonry dams that were quite water-tight from the first filling of the reservoir, although "sweating" appears at several points on the lower face. The dam was built by the aid of a 2-inch cableway, stretched along its axis, with a span of 667 feet between towers. The Sodom reservoir covers an area of 574.9 acres and impounds 4,883,000,000 gallons. The Bog Brook reservoir, with which it is connected, floods a surface area of 410.4 acres. The Bog Brook dams are of earth with masonry core. Dam

No. 1 is 60 feet high and holds 54 feet maximum depth of water. It is 25 feet wide on top. The core-wall is 10 feet thick at base, 6 feet at top. Dam No. 2 is 25 feet high. The cost of the two dams was $510,430.

The Boyd's Corner Dam, New York.—In 1866 the Croton Aqueduct Board of New York began a masonry dam near Boyd's Corners, on the west branch of Croton River, which was completed in 1872. The dam contains 27,000 cubic yards of masonry, of which 21,000 yards are concrete hearting and 6000 yards are cut-stone facings. The dam has a maximum height of 78 feet, is 670 feet long on top, 200 feet long at level of stream-bed, 53.6 feet thick at base, 8.6 feet at top. The base is laid with a batter of $\frac{1}{2}$ to 1 on each side to the original stream-level, 60 feet below the crest, where an offset of 1.5 feet was made on each side, and the dam was then carried up vertically on the water-face, and given a batter of 0.4 to 1 on the lower side. The reservoir covers 279 acres and impounds 2,722,700,000 gallons of water.

The Indian River Dam, New York.—This important structure was erected in 1898 for increasing the size of Indian Lake and thus store water to supply the Champlain Canal, to add to the water-power, and to improve the navigation of Hudson River. It is located in Hamilton County in the northern part of New York State, on a tributary of the Hudson, at an elevation of 1655 feet at the high-water line. The dam is a combination masonry and earth structure, straight in plan, the masonry portion being 47 feet in extreme height, having a base width of 33 feet, a thickness on crest of 7 feet, and a total length of 207 feet. The earth embankment is a continuation of the masonry, 200 feet long, 15 feet wide on top, with inner slopes of $2\frac{1}{2}$ to 1, paved with 12 inches of stone riprap. The outer slope is 2 to 1. Through the center is a core-wall of masonry, 4 feet thick at base, 2 feet at top, reaching to within 2 feet of the crest of the embankment. The end of the embankment next the dam is supported on the down-stream side by a masonry spur-wall at right angles to the dam. The embankment rests on hard-pan, into which the core-wall is carried down uniformly 4 feet thick to depths of 8 to 20 feet, filling the trench cut for it.

On the opposite or west end of the dam a spillway was excavated in granite, having an effective length of 106.5 feet and a depth of 6 feet, to the bottom of the floor-stringers of the foot-bridge which spans it and which rests on five masonry piers. The capacity of discharge is estimated at 5000 second-feet. The coping is made of large, selected stones firmly doweled to the masonry. A logway, 15 feet wide, whose crest is 17 feet below the top of the dam, is provided through the masonry. It is closed with 45 wooden needles, $4'' \times 8''$, 20 feet long, which are handled by block and tackle. The outlets to the reservoir consist of two 50-inch steel pipes, controlled by Eddy flume-gates, and having a discharging capacity of 1500 second-feet with full reservoir. The gates are inside of a tower, on the

exterior of which are auxiliary sluice-gates of wood, raised by screws. A 6-inch by-pass pipe enters the tower from the reservoir, by which the tower is filled and the pressure relieved from the wooden gates, so that they can be readily raised.

The total actual cost of the work, including $13,000 for clearing, was $83,555, the contract price being $92,000. Under the most favorable conditions the cost per cubic yard for the masonry was as follows:

Cement	$2.00
Sand	.15
Quarrying stone	.35
Labor of laying masonry	.53
Labor of pointing masonry	.15
Labor of mixing mortar, concrete, and crushing	.20
General expenses, superintendence, etc	.27
Total	$3.65

The cement used was made at Glenn's Falls, N. Y., of the "Ironclad" brand of artificial Portland.

The reservoir formed by the dam has a storage capacity of 4,468,000,000 cubic feet, or 102,548 acre-feet, and floods an area of 5035 acres. The original lake covered 1000 acres, and the new dam raised the mean surface of the lake 33 to 34 feet. The tributary drainage-area above the dam is 146 square miles, the run-off from which can be safely estimated to fill the reservoir every year.

The dam was built for the Forest Preserve Board of New York State by the Indian River Company. It was planned by Geo. W. Rafter, M. Am. Soc. C. E., and constructed under his supervision by Wallace Greenalch, Jun. Am. Soc. C. E., as Assistant Engineer.

For further details of this interesting work the reader is referred to *Engineering News* of May 18, 1899, containing descriptive illustrated papers on the subject by Messrs. Rafter and Greenalch.

Cornell University Dam, New York.—In 1897 an overflow masonry dam was built across Fall Creek near Ithaca, N. Y., as a portion of the hydraulic laboratory plant of Cornell University. It is curved in plan on a radius of 166.5 feet, and is 153 feet long on top, with a maximum height of 30 feet, and a gravity section, vertical up-stream, and stepped on the lower face. It is located at the head of Triphammer Falls, in a picturesque gorge, cut deeply into the shale formation of that region, where the total fall is about 400 feet in a mile. The stream drains a watershed of 117 square miles, on which the mean precipitation from 1880 to 1897 was 35.22 inches. The mean flow is about 175 second-feet, ranging from a minimum of 12 to a maximum of 4800 second-feet. In times of flood the water discharges over the crest of the dam and over a natural spillway ledge at one end of the dam, a total width of 267.5 feet, made up of 134.5 feet on the dam and 133 feet on the natural spillway.

The dam is of gravity section, and made of concrete, composed of four parts of hard, clean, argillaceous shale, two parts of sand, and one part of "Improved cement." The "Improved cement" is a mixture of Rosendale and artificial Portland in the proportion of weight of 3 to 1, ground together in the clinker state, and costing one-half the cost of pure Portland cement.

One of the interesting and unusual features of the construction of this dam was the provision made for concentrating the contraction due to temperature changes in the concrete to a central point of weakness. This was done by leaving a 5-ft. circular opening through the dam during construction, connecting with which was an open well extending up through the heart of the dam to its crest. At this point the section was thus reduced to 60% of the normal, and shortly after completion the wall cracked for one-half its height down through the well. During unusually cold weather, when the crack was widest, the opening through the dam and the well were filled with concrete, and the contraction-crack was thus effectually closed.

The dam and other works connected with the entire plant designated as the hydraulic laboratory were designed by Prof. E. A. Fuertes, M. Am. Soc. C. E., Director of the College of Civil Engineering. Construction was in charge of Mr. Elon H. Hooker, Resident Engineer. Mr. Ira A. Shaler, M. Am. Soc. C. E., was contractor for the work. A full description of the laboratory is given in *Engineering News*, March 2, 1899.

The Bridgeport Dam, Connecticut.—The town of Bridgeport, Conn., having a population in 1890 of 48,890, is supplied by a number of storage-reservoirs, one of which is formed by a masonry dam across Mill River, built in 1886. Its general dimensions are as follows:

Maximum height	42.5 feet.
Bottom thickness	32.0 "
Top thickness	8.0 "
Length at crest	640 "
Length at base	50 "

The structure is composed of rubble masonry built of gneiss rock laid in a mortar of Rosendale cement and sand in the proportion of 1 to 2. The lower face of the dam is built in steps. The outlet from the gate-chamber is a 30-inch cast-iron pipe, controlled by a gate-valve in the chamber. The latter structure is built against the dam, is 10×15 feet inside, in two compartments, between which a fish-screen is placed. Three 30-inch openings, at different levels, controlled by gates, lead from the reservoir to the outer compartment. The spillway, at one end of the dam, is 80 feet long, 5 feet deep. The reservoir covers 60 acres and has a capacity of 240,000,000 gallons (737 acre-feet). The dam has leaked so much as to require an earth backing.*

* "The Design and Construction of Dams," by Edward Wegmann, p. 128.

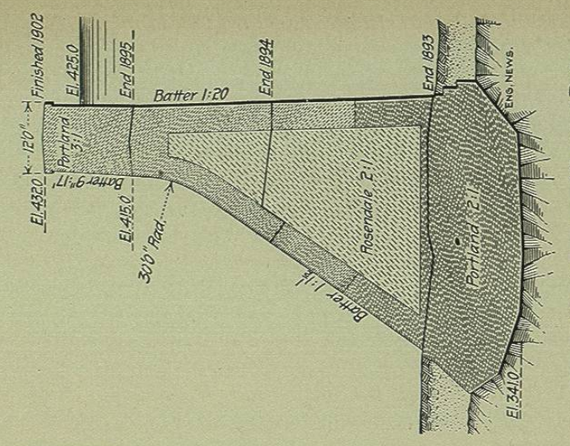

FIG. 227.—SECTION OF WIGWAM DAM.

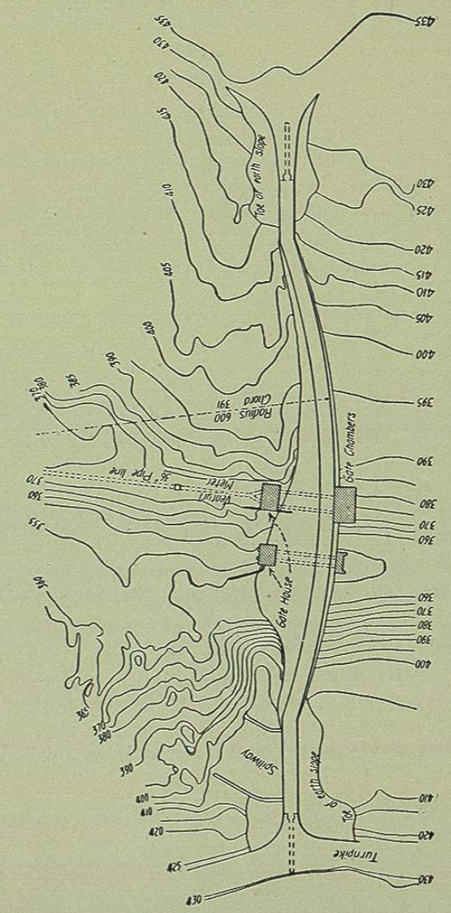

FIG. 226.—PLAN OF WIGWAM DAM, CONNECTICUT.

The Wigwam Dam, Connecticut.—The city of Waterbury, Conn. (pop. 30,000 in 1897), constructed a masonry dam in 1893–94 to store water in a reservoir located on West Mountain Brook and receiving the drainage from 18 square miles of watershed. The dam was designed and built by Robt. A Cairns, City Engineer. It was planned for an ultimate height of 90 feet, at which its full length on top will be 600 feet, and it was completed with full section to within 15 feet of the ultimate crest, and there stopped, as the storage at that level was sufficient for present needs. The base thickness is 62.08 feet, and it is 12 feet thick on the crest. The cubic contents of the completed portion are 14,887 cubic yards, of which 5754 yards are laid in Rosendale cement, and the remainder in American Portland cement mortar. The cost has been $150,000. The present capacity of reservoir is 335,000,000 gallons (1028 acre-feet), which will be increased to 714,000,000 gallons when the dam is completed. A temporary wasteway, 82 feet long, 2 feet deep, has been made at one end of the dam, which is of insufficient capacity. The completed dam will have a wasteway 100 feet long over a rocky ridge some distance away, and another 78 feet long at the dam. An earth embankment is required to close a gap in the reservoir, as an auxiliary to the masonry dam. This will be 35 feet high when finished, but is built only to a height of 20 feet.

The Austin Dam, Texas.—The city of Austin, Texas, the capital of the State, with a population of about 25,000 inhabitants, has erected one of the most notable masonry dams of the United States, across the Colorado River, 2½ miles above the city, for power-development purposes. The dam, Fig. 228, was built in 1891–92. It was designed by Mr. Jos. P. Frizell, M. Am. Soc. C. E. of Boston, and about two-thirds completed by him. He was succeeded by Mr. J. T. Fanning. The dam proper is 1091 feet long between bulkheads and 68 feet high. It is vertical on the up-stream face, while the down-stream face is inclined at a batter of 3 in 8, terminating in a vertical curve of 31 feet radius, while the crest is rounded on a radius of 20 feet on lower side, forming an ogee curve that has the general shape of the trajectory of falling water.

Mr. Frizell's original design contemplated a flat top for the purpose of facilitating the erection on the crest of a series of movable flashboards, or some other form of falling dam, that could be lowered in flood-time, but would permit of increased storage during low seasons, and the development of a more uniform volume of power at low and high water.

The power is used for pumping water for city supply, for electric lighting, propulsion of street cars, and general manufacturing. Its volume is estimated at 14,636 horse-power for 60 working hours weekly.

The dam is straight in plan, and contains about 88,000 cubic yards of masonry, of which 70,000 yards are of rough rubble, made of the limestone quarried near the site, and 18,000 yards are of cut-stone range-work, in

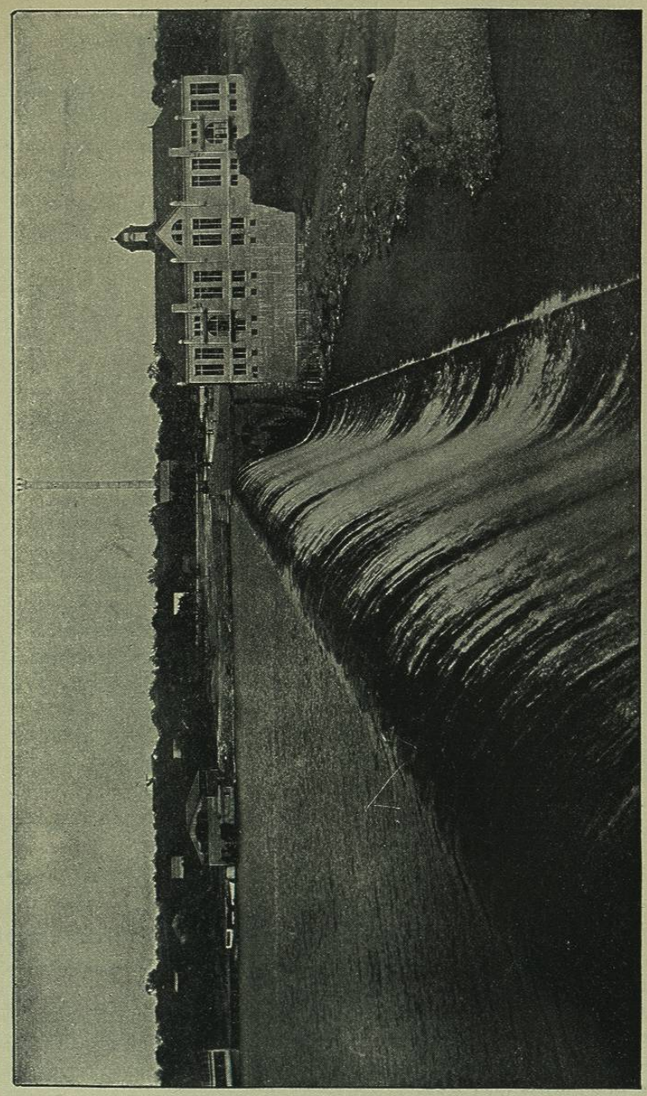

FIG. 228.—AUSTIN DAM AND POWER-HOUSE, TEXAS.