PLATES.

RESERVOIRS FOR IRRIGATION, WATER-POWER, AND DOMESTIC WATER-SUPPLY.

CHAPTER I.

ROCK-FILL DAMS.

THE natural fertility of resource in the American people has led to many novel experiments in the construction of dams to adapt them to the materials most conveniently available, and this has resulted in the development of numerous interesting types. Among these the most conspicuous are the rock-fill dams, which may be said to have originated about the middle of the last century in the mining region of California, where dams were built in remote and almost inaccessible locations, to which the transportation of cement was impracticable. These were considered to be of a temporary nature, where dams of permanent masonry were not warranted, but where a water-supply for mining purposes needed to be impounded. They began with timber or log cribs filled with loose stone. Their next stage was an embankment of loose stone a portion of which was laid up as a dry wall, with a facing of two or more thicknesses of plank to secure water-tightness. The latter type has proven so serviceable that it is still regarded as one of the most desirable classes of dam that can be built, where economy is of prime consideration. In the attempt to secure a greater degree of durability other types have been developed as follows:

1. Rock-fill dams with a vertical central core of steel plates, protected with a coating of asphaltum and burlap, and supported by thin concrete walls on each side.
2. Rock-fill dams with a facing of steel plates riveted to I-beams laid on the inner slope of the embankment at an angle varying from about 20° off the vertical to about 45°, the wall being hand-laid to a sufficient thickness to give requisite stability.
3. Rock-fill dams, with face of masonry, built vertically or slightly inclined, backed with earth or rock, and protected on the lower slope by a covering of stone laid in mortar.
4. Rock-fill dams with facing of Portland cement-concrete, either reinforced with steel rods or expanded metal, or without such reinforcement.
5. Rock-fill dams with facing of earth.

6. Rock-fill dams with inner core-wall of wood, faced with earth sluiced in position, filling the voids in the rock above the wood partition; generally called the "combination rock-fill and hydraulic-fill dam."

7. Rock-fill with facing of concrete.

Existing examples of these various types and their variations will be considered in the following pages.

The Escondido District Dam, California.—Few of the irrigation districts organized in California under the well-known Wright law have been suc-

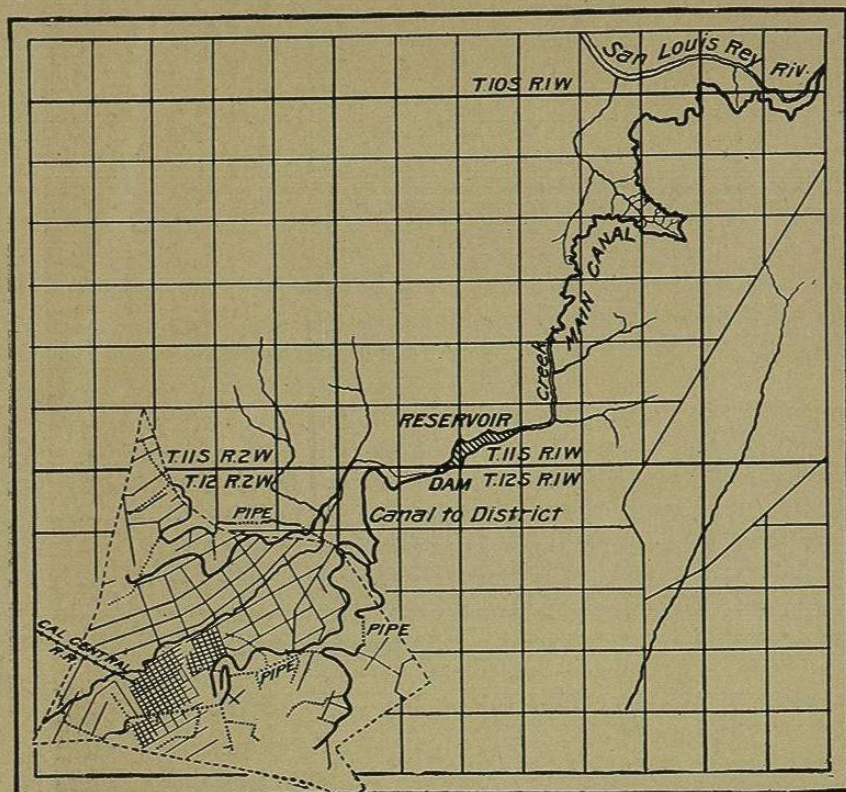

Fig. 1.—Map of Escondido Irrigation District and System of Works.

cessful in accomplishing the purpose of their organization, and many disastrous and lamentable failures have to be recorded in the practical operation of a law which, at one time, was looked upon as a wise and feasible measure for the general irrigation of the arid lands of the States. Among the very few that succeeded in selling bonds and constructing a storage-reservoir and distributory system is the Escondido district in the northern portion of San Diego County. The district (Fig. 1) is in a valley whose description is implied by its Spanish name, Escondido—hidden. It is surrounded by mountains and embraces 13,000 acres. The storage-dam supplying the district is located on the Von Segern branch of San Elijo

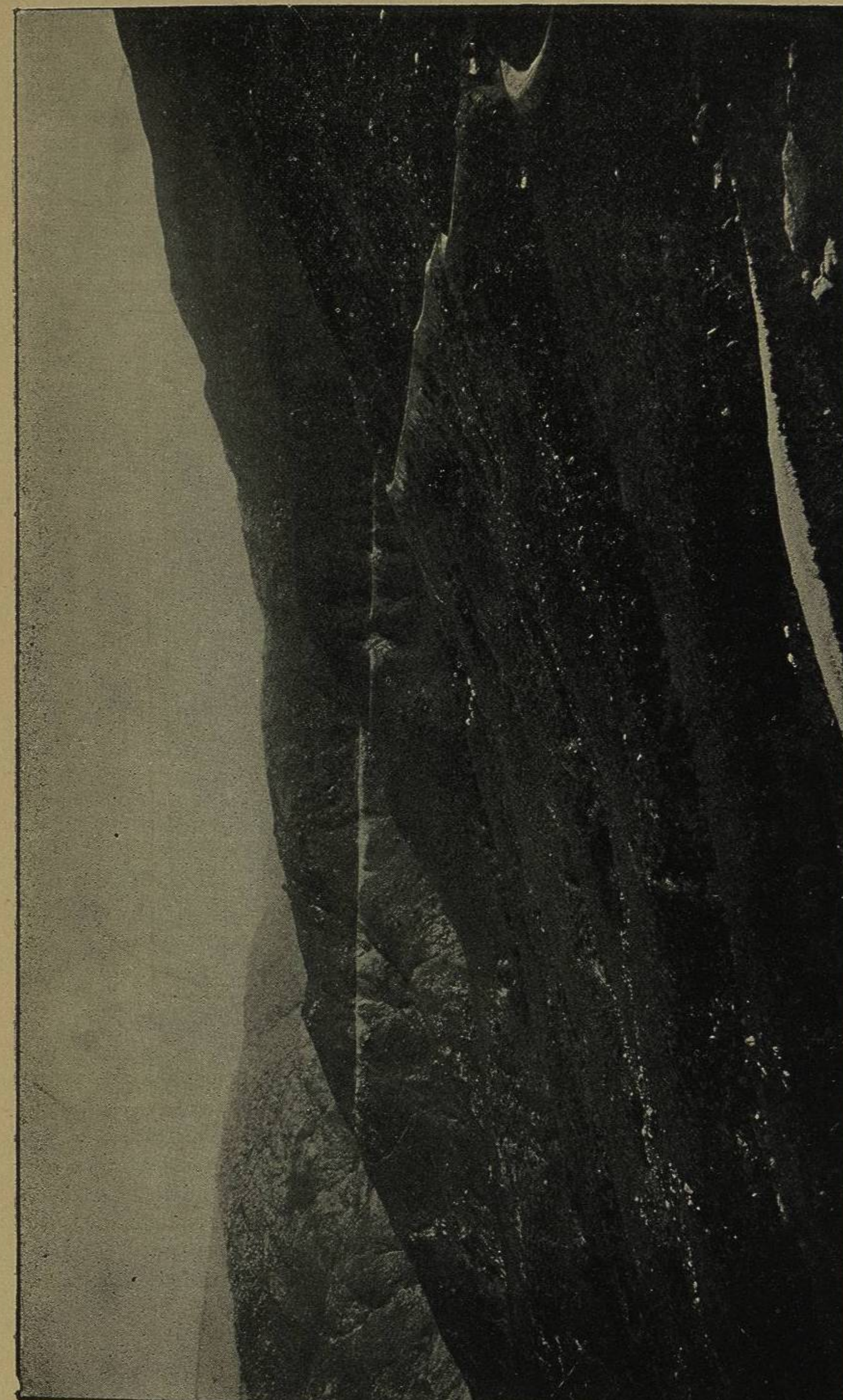

Fig. 2.—Feeder Canal on the Side of Rodriguez Mountain, Escondido Irrigation District.

Creek, which passes through the town of Escondido. It is about two miles east of the district at its nearest point, and at an elevation of 1300 feet above sea-level, or about 650 feet above the town.

The immediate watershed tributary to the reservoir measures about 8 square miles, which in that region affords insufficient run-off to fill the reservoir, although adding materially to it at times of heavy rainfall. Hence the main supply had to be brought to it from the San Luis Rey River, the nearest stream to the north, by a conduit which taps the river at an altitude of 1600 feet, in a wild, rocky canyon, which is almost inaccessible by reason of its roughness. The conduit has a capacity of 28 second-feet, and is 5.6 miles long, consisting of 67,287 feet of ditch built along the rugged mountain-side (see Fig. 2), 14,142 feet of flume, and 806 feet of tunnel. The intake is made by a tunnel 356 feet long, heading in the river 3 feet below low-water level, while at the other end the rim of the reservoir-basin is pierced by a second tunnel 450 feet long. This tunnel discharges into a ravine leading down to the dam, 3½ miles below. The intake tunnel is cut through solid granite, which is excavated below grade at its lower end to form a settling-basin, in which sand accumulates at the rate of about 1000 cubic feet daily. This is sluiced back into the river by the opening of a side outlet-gate. By this means the water of the conduit is kept comparatively clear and but little sediment has accumulated in the reservoir.

The upper 8000 feet of the conduit consists of a flume (Fig. 3), supported on posts on the sides of a rugged canyon, which in places presents a vertical face of considerable height. The lumber of this flume was hauled by a roundabout road to a bluff on the opposite side and 600 feet above the river-bed, whence it was transported by a wire cable with a span of 1500 feet by means of a trolley manipulated by hand windlass and rope. At other points the lumber was hoisted to the line by horse-power, by means of a car and portable track several hundred feet in height. The flumes are mainly 4 feet wide by 3 feet deep, and the ditch is excavated with a bottom width of 5 feet and side slopes of 1 on 1, the minimum excavation on the lower side being about 3 feet. The formation throughout that region is granitic, partially decomposed, the disintegration of the rock forming a few feet of soil, from which protrude large bowlders of very hard granite embedded in softer rock *in situ*.

The total cost of the conduit was $116,328.60, or $1.29 per foot for construction and engineering, and 12 cents per foot for right of way, commissions, etc. The conduit is capable of filling the reservoir to its present capacity in a little over sixty days when running to its full capacity. Should the dam be completed to the height of 110 feet as it has been projected, the conduit would require to run full for rather more than six months to fill the enlarged reservoir.

In seasons when the precipitation exceeds 20 inches the run-off from the

immediate watershed above the dam is alone expected to fill the reservoir as at present constructed. For the preservation of the main conduit, of which nearly 20% is wooden flume which should be kept wet for proper maintenance, it would be desirable to maintain a flow of water through it the entire season. For this purpose the construction of an auxiliary reser-

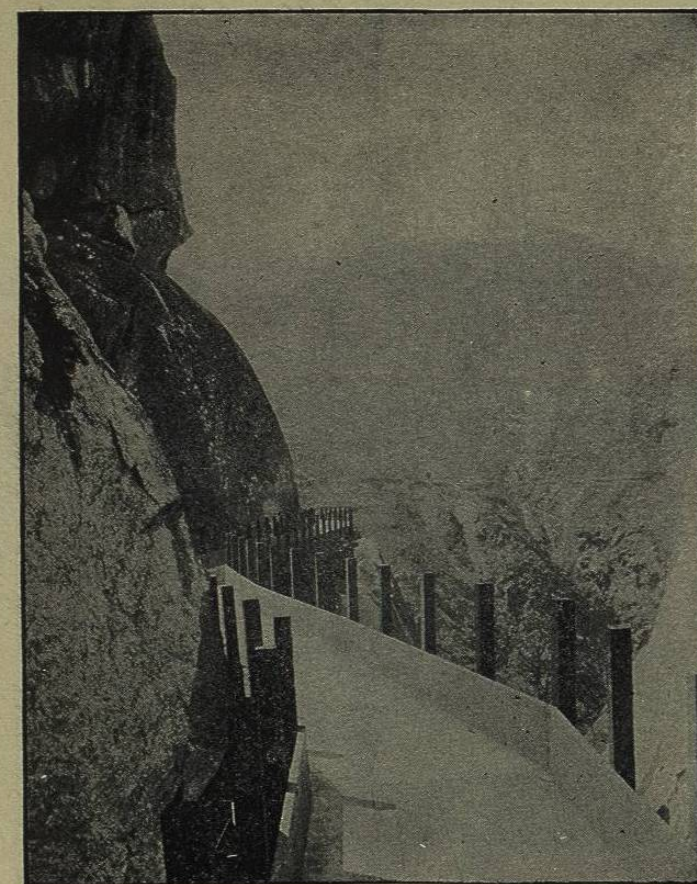

Fig. 3.—Feeder Conduit of Escondido Irrigation District.

voir at the head of the conduit is regarded as one of the most desirable of the projected improvements to the system. A very capacious reservoir-site exists at Warner's Ranch, 15 miles above the head of the canal, where the drainage of 210 square miles of watershed may be impounded. A much greater volume of water can here be stored than would be needed by the district. In fact the capacity of a reservoir with a dam 100 feet high at this point would be 193,200 acre-feet, covering 5535 acres, which is far beyond the probable yield of the watershed in years of maximum rainfall.

A cross-section of the dam-site is shown in Fig. 177, where the width of the site at 100 feet is seen to be but 590 feet. A more modest dam of earth, 36 feet high, to hold 30 feet depth of water and to impound 6400 acre-feet in a reservoir covering 740 acres, would serve all the requirements of the

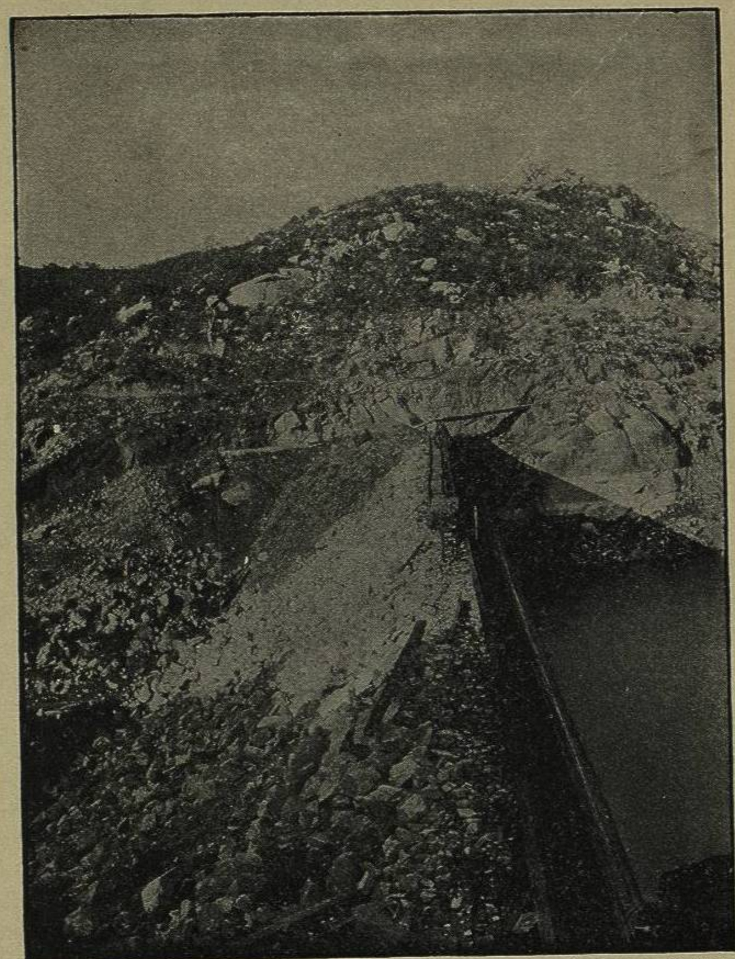

FIG. 4.—ESCONDIDO IRRIGATION DAM, LOOKING NORTH, SHOWING SPILLWAY.

district and at moderate cost, provided the land is obtained at reasonable rates.

The Escondido dam is of the ordinary type of rock-fill, with facing of redwood plank. In this respect it resembles the mining dams of northern California, although the use of redwood has given the facing a longer life than the more perishable pine used in the North. This structure appears to have been built with unusual care, and though ragged and unfinished in appearance, it is of ample dimensions for the pressures it withstands and is

reasonably water-tight. It is 76 feet high, 380 feet long on top, 100 feet on bottom, with a base of 140 feet, and a thickness at the crest of 10 feet. A spillway has been excavated at the north end on the right bank of the reservoir, in solid rock, 25 feet wide, its bottom being at the 71-foot contour, or 5 feet below the crest of the dam. This is left open and unobstructed, although it has been customary near the end of the rainy season to build a barrier of sand-bags across it in order to impound a greater depth of water, after the danger of floods is presumed to be over.

The slopes of the dam are ½ to 1 on the water-face, and on the back 1 to 1 for half the height, flattening to 1¼ to 1 from mid-height to base. The cubical contents are 37,159 cubic yards, of which 6000 yards were hand-laid in courses of dry rubble on the face, the thickness of the wall being 15 feet at bottom, and 5 feet at top. The remainder consists of loose, angular blocks of granite, of all sizes up to 4 tons weight (Fig. 5), which were loosely dumped from cars and placed to some extent with derricks. No small quarry-spawls or earth were used, and the result is a clean rock-fill, which has not settled more than three inches since its final completion. No large ledges affording well-defined quarries of any considerable extent were uncovered in the course of construction, but all the material was taken from scattered bowlders and rock-masses protruding on either side of the canyon above and below the dam for a distance of 800 feet. Temporary tramways were built at different levels on either side, as the dam rose in height, so arranged as to permit the cars to run to the dam by gravity, the empty cars being hauled back by horses. These tracks were carried across the dam on elevated trestles, the posts of which remain buried in the embankment. This arrangement involved the pushing of the cars across the trestle by hand, which was a slow and expensive process. The entire method of work was costly and inconvenient compared with the modern systems of cableway transportation of such materials.

In stripping the foundations bed-rock was found about 4 feet below the bed of the creek, nearly level across the canyon from side to side. The top soil was removed over the entire base of the dam and the filling of rock placed directly upon the granite foundation. The bed-rock was of the formation described as prevailing along the main conduit, which is a common characteristic of southern California, and consists of disintegrated granite holding hard bowlders indiscriminately through it. The formation is not impervious to water, and for that reason is not considered a desirable or satisfactory foundation for a heavy masonry dam because of the resultant upward pressure on the base due to that condition, but for a rock-fill structure of this class it is unobjectionable. Into this bed-rock a trench was excavated at the upper toe of the dam, from 3 to 12 feet deep, which was refilled with rubble masonry 5 feet thick, laid in Portland-cement mortar. Into this masonry was embedded the plank facing, which was thus

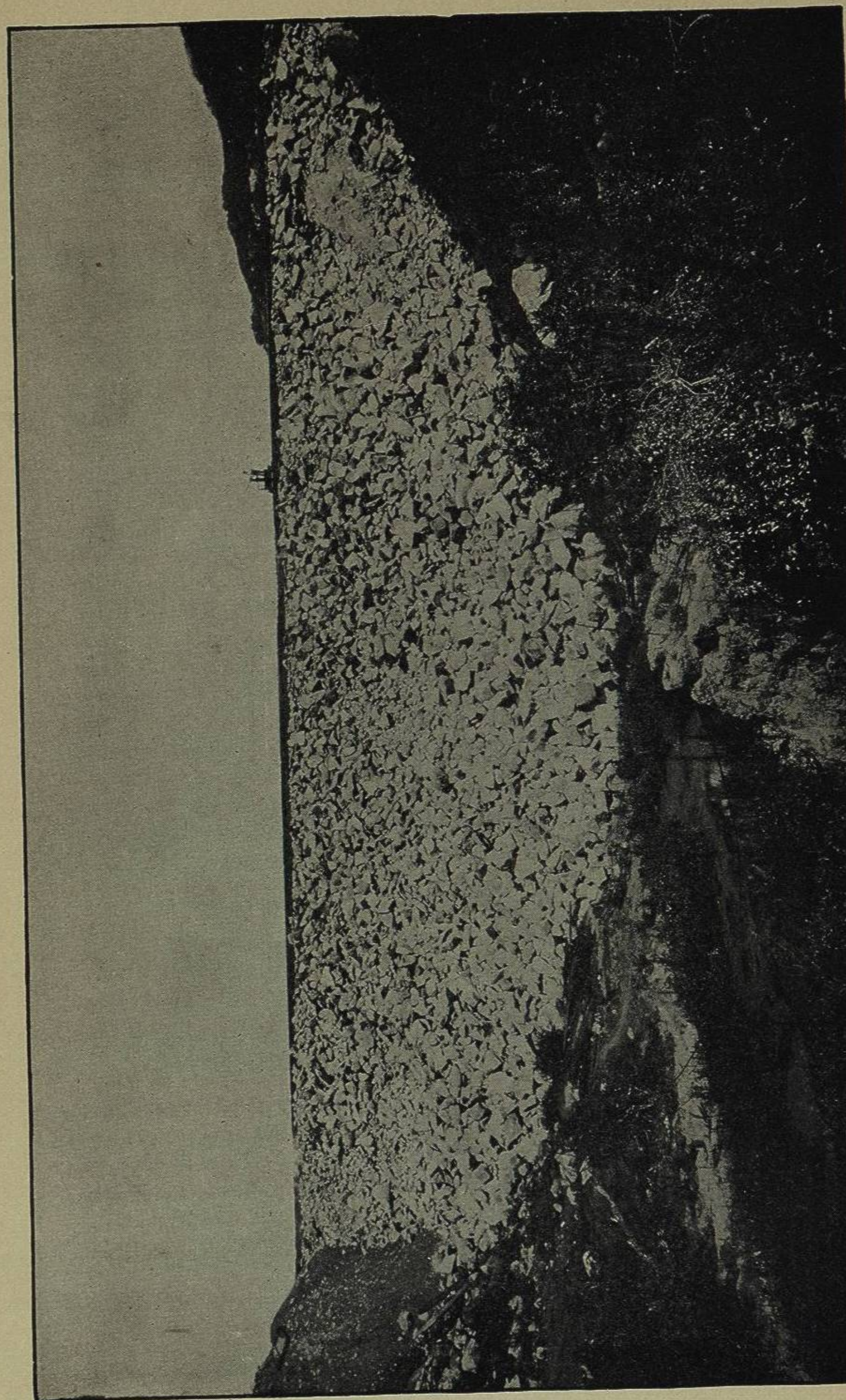

Fig. 5.—Back of Escondido Irrigation District Dam.

connected all around the toe with the canyon walls and bed. The dry wall forming the upper face of the dam was so laid as to embed in its surface a series of redwood timbers, 6″ × 6″ in size, placed in vertical parallel lines, 5 feet 4 inches apart between centers. These timbers projected 2 inches beyond the face of the wall, and the planks were spiked to them. As each row of plank was put in position, beginning at the bottom, concrete was rammed into the 2-inch space between the plank and the face of the wall, giving a full bearing for the plank throughout. This provision was certainly a wise one, and so far as the writer is informed was never employed before in the dams of this class previously constructed. On the lower third of the dam the facing plank are 3 inches thick, on the middle third 2 inches, and on the upper third 1½ inches, all being doubled throughout. Joints were broken as far as possible, both at the vertical and the horizontal seams, by the second layer, and they were calked with oakum and smeared with hot asphaltum.

Springs of water were developed in the excavation of the foundation to the extent of 30,000 to 40,000 gallons per day, constant flow. These were led out by pipes to the outer toe. The leakage through the dam when filled to the 47-foot level was found to be 130,000 gallons daily, exclusive of the springs. This increased to 450,000 gallons daily when the reservoir filled to the top. It is not known whether this leakage comes through the joints of the facing or percolates through the disintegrated granite beneath the dam. Whatever may be its origin, it is entirely harmless as far as can be observed, and is not a source of anxiety. In the winter months when irrigation is not required this leakage-water is used for domestic service, and the whole of it is at all times picked up by the diverting-dam and carried into the distributing system. Hence it occasions no direct loss of water. While this amount of leakage would be dangerous to an earth dam, and even in a masonry structure would indicate the existence of an upward pressure that might endanger its stability if the section were too light, yet in a work of this nature the drainage through the open, loose rock is so perfect that the gravity of the mass is not lessened or disturbed by it, and no serious consequence can be anticipated.

The facing-planks have been carried up 3 feet higher than the top of the rock-fill as a wave protection, so that the extreme crest is 9 feet above the floor of the spillway as shown by the section illustrated in Fig. 6.

The outlet was originally designed to be controlled by means of a tower, the foundations of which were laid at the upper toe of the dam near the south end, but the plan was changed and a grating placed over the base of the unfinished tower a few feet above the gate covering the outlet. The gate is of cast iron with brass facings, set in a frame, also faced with brass, and bolted to the cast-iron outlet. It is set at the incline of the upper slope and is controlled by a long rod resting in guides at frequent intervals,

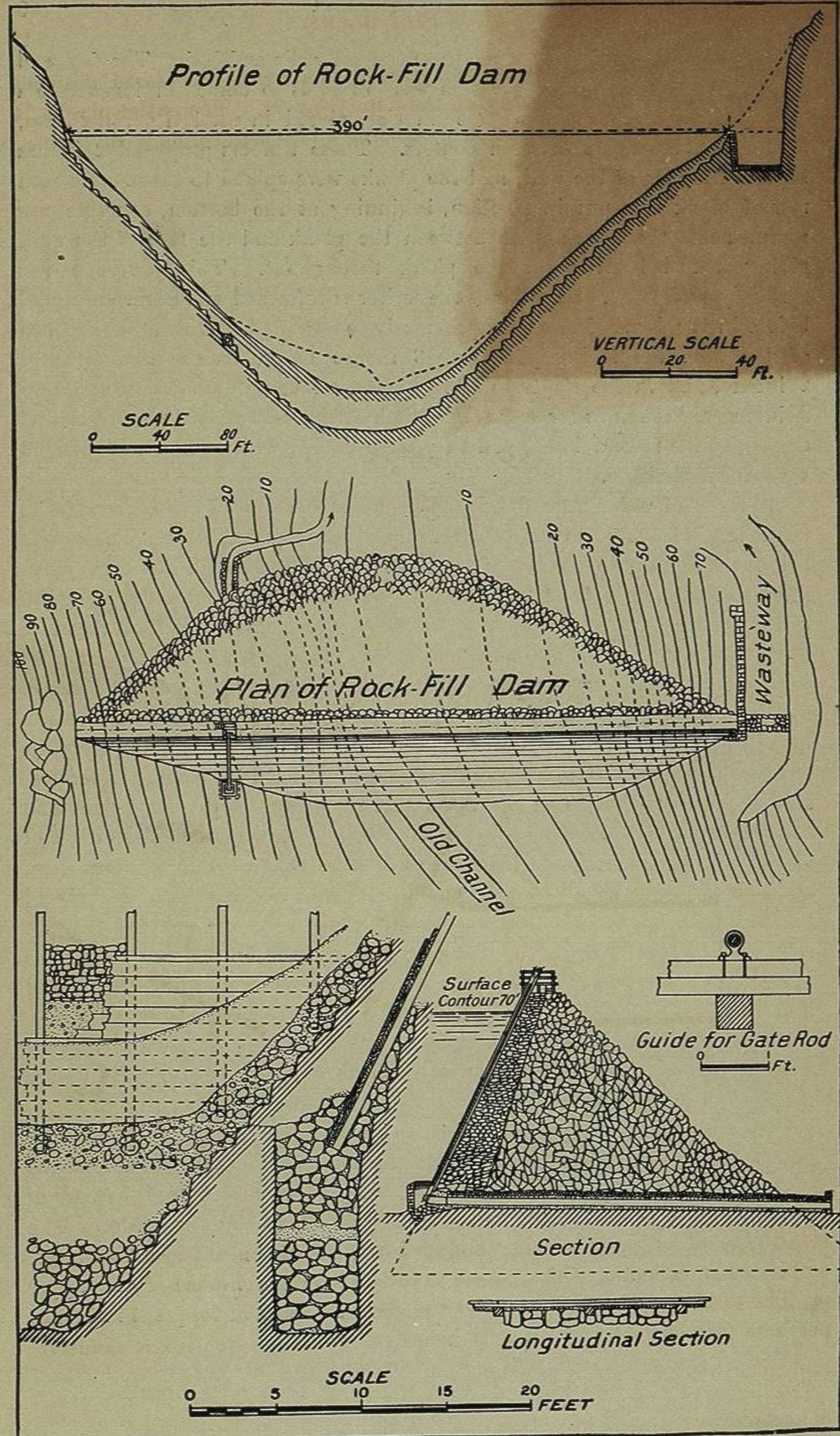

Fig 6.—Plans and Profiles of Escondido Dam.

fastened to the wooden facing, and leading to a worm-gear placed at a convenient height above the top of the dam (Fig. 7). The outlet-pipe is 24 inches in diameter, consisting of a cast-iron elbow connecting with vitrified

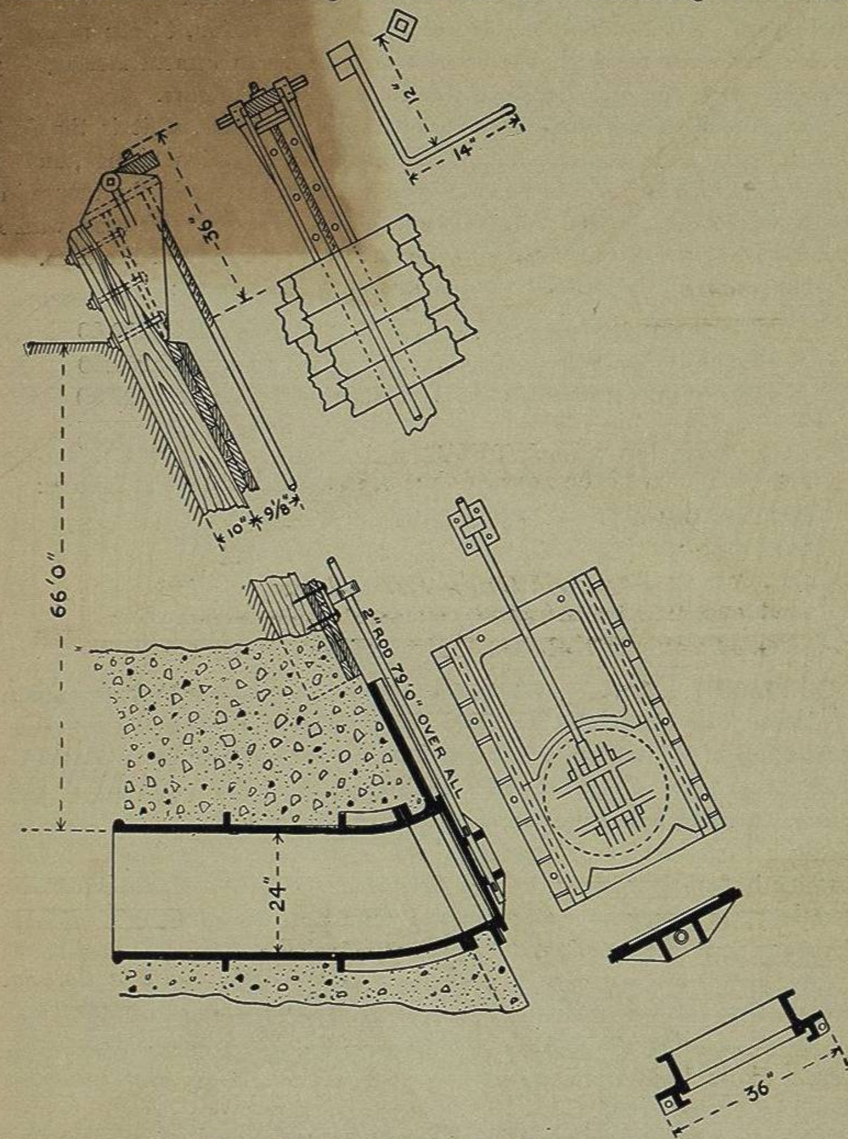

Fig. 7.—Details of Gate of Escondido Dam.

sewer-pipe of ordinary weight, laid in a trench cut in the bed-rock and embedded in concrete, which covers it fully 12 inches in depth.

The total cost of the dam under the contract was $86,946.21, or $27.82 per acre-foot of reservoir capacity below the spillway level. The land for