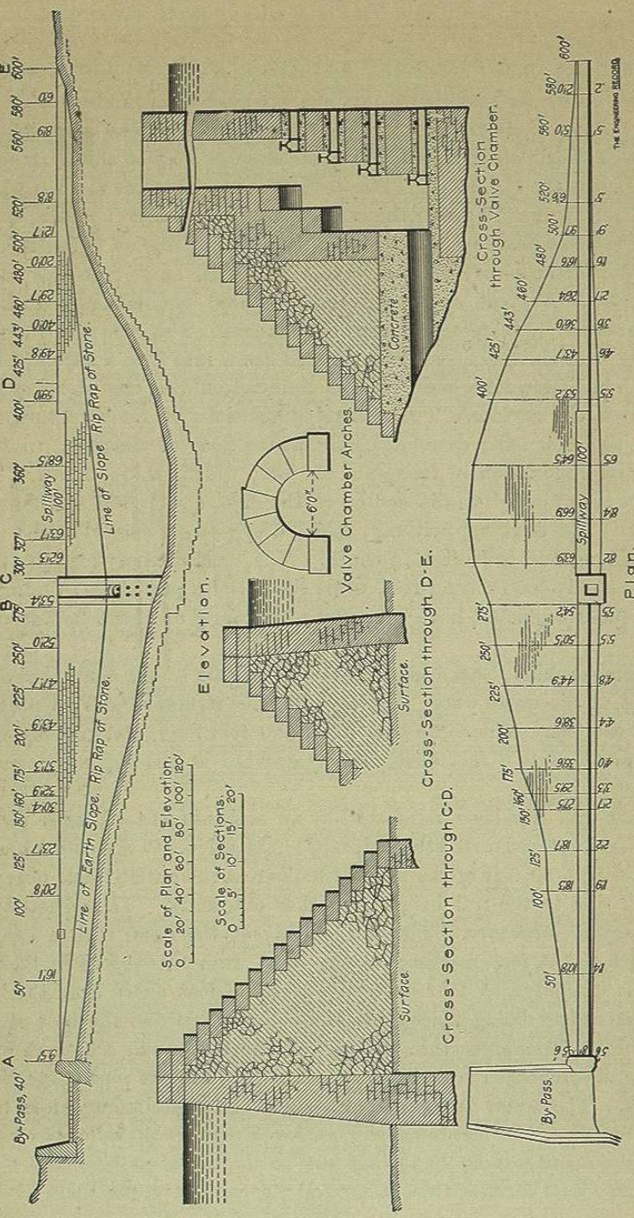

FIG. 26.—CASTLEWOOD DAM, COLORADO; PLAN, SECTIONS, AND ELEVATION.

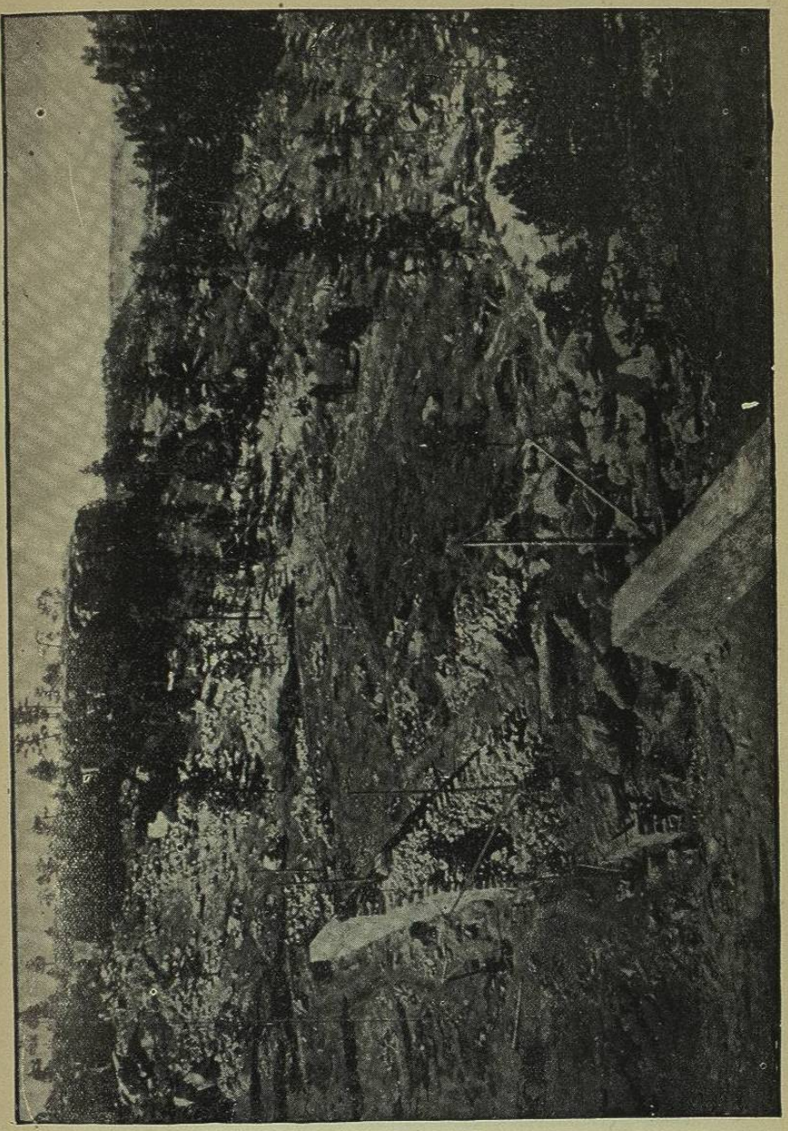

FIG. 27.—VIEW OF CASTLEWOOD DAM, COLO., DURING CONSTRUCTION, LOOKING NORTH.

reservoir has a surface area of 60 acres and a capacity of 700 acre-feet, its maximum depth being 16 feet.

The construction of the Castlewood dam was attended by much opposition from the citizens of Denver, who were apprehensive of its

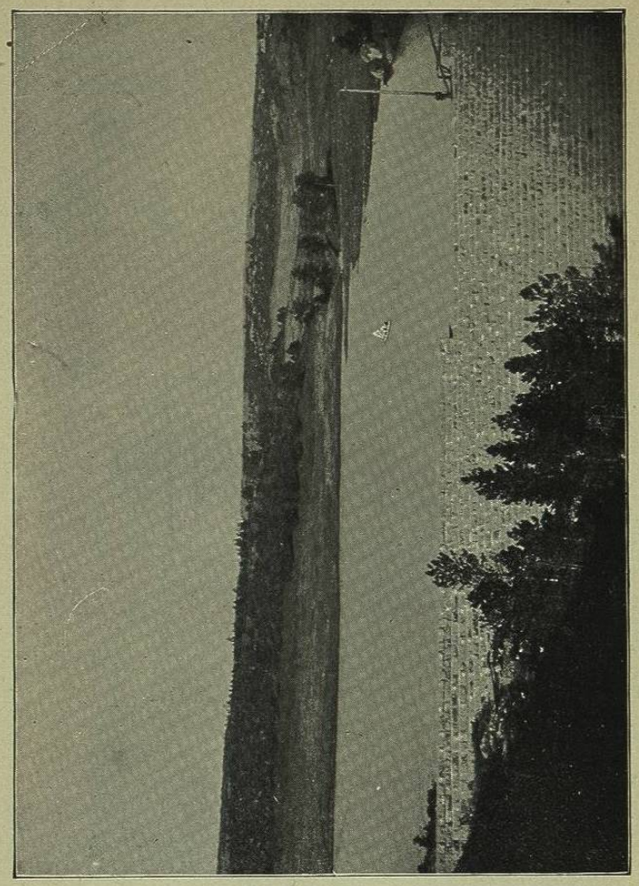

FIG. 28.—VIEW OF CASTLEWOOD DAM AND RESERVOIR, COLORADO.

safety and severely criticised the plan. Unsuccessful attempts were made to enjoin the construction, but it was finally permitted to be completed.

On April 30, 1900, after a very heavy rainfall exceeding all previous records, the reservoir was filled, and it was reported that 500 cubic feet per second passed over the top of the dam, and through the 40-foot

FIG. 29.—CASTLEWOOD DAM, COLO.

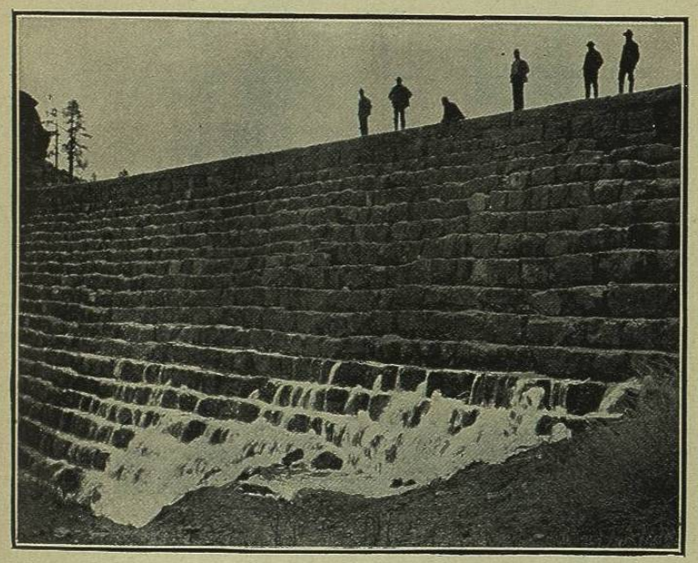

FIG. 30.—CASTLEWOOD DAM, COLO., SHOWING LEAKAGE THROUGH ROCK-FILL.

spillway at the side, while the discharge pipes were wide open. At the same time a large volume of water found its way through the cracks in the masonry wall, and poured out in large streams through the rock-fill for 10 to 15 feet above the base.

The photograph, Fig. 30, shows an enormous amount of this leakage, and the cause for the alarm created in Denver, which lies directly in the path of the escaping water. That the dam was able to withstand such a volume of leakage is a testimonial to the stability of rock-fill dams, which in this case afforded such complete drainage as to be unaffected by leakage that would immediately have destroyed an all-earth dam.

Subsequently repairs were made in the manner illustrated by Fig. 31, taken from *Engineering Record.*

An earth embankment, 8 feet wide on the crest, was built on the up-stream side to the full height of the rock-fill, with slope of 3 on 1,

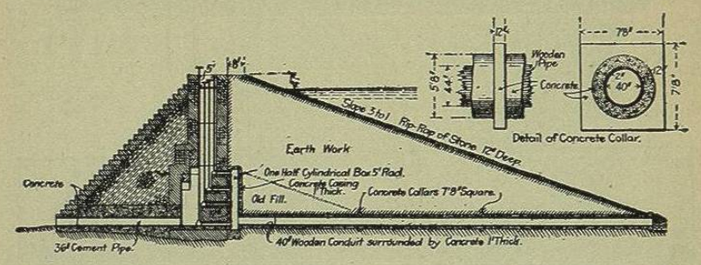

Fig. 31.—Castlewood Dam, Colo. Section after Reconstruction.

faced with 12 inches of riprap. Underneath this embankment the outlet pipe was extended from the valve chamber to the up-stream toe by building a 40-inch woodstave pipe, surrounded with reinforced concrete 1 foot thick. This pipe connects with a steel box encased in concrete, into which all of the eight 12-inch pipes that pass through the masonry make connection.

The 40-foot spillway, which had been seriously damaged in the flood, was repaired, and another one, 12 feet wide, with side slopes 1 on 1, was built at the opposite end. The dam in its present condition, as reconstructed, is practically a combination rock-fill and earth embankment, having a masonry core-wall throughout, and is manifestly a safe and substantial structure. The dam was planned and built by A. M. Welles, C.E., of Denver, with Mr. Alfred P. Boller, M. Am. Soc. C. E., of New York, as consulting engineer.

Pecos Valley Rock-fill Dams, New Mexico.—Two rock-fill dams with earth facings have been constructed across the Pecos River, in the Pecos Valley, New Mexico, which have boldly and successfully exemplified a distinct type of dam that is considered to be preferable to all other rock-fills where the proper conditions exist and suitable materials are obtainable. One of these dams is located 6 miles and the other 15 miles above the town of Carlsbad, N. M. They were built by the Pecos Irrigation and Improvement Company.

Lake Avalon Dam.—The lower dam, designated locally as the Lake Avalon dam, was built primarily as a means of raising the level of water of the river in order to divert it into a canal at a safe height above the reach of maximum floods, and at the same time to equalize the flow by providing

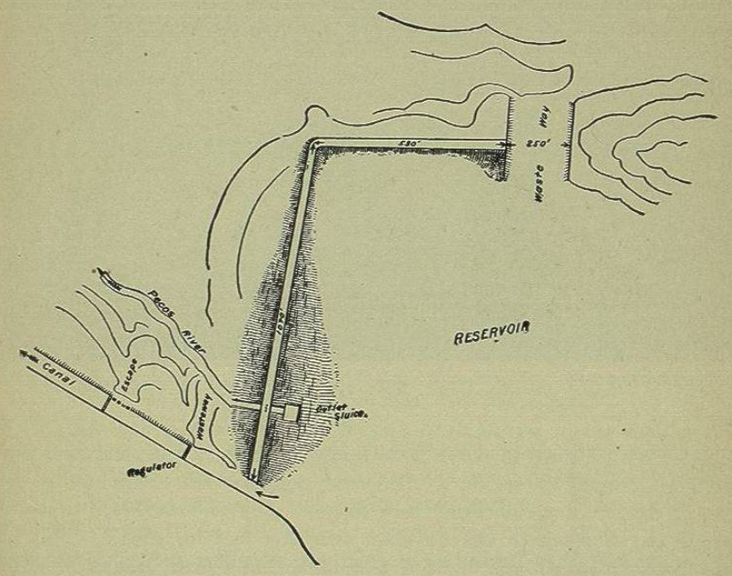

Fig. 32.—Sketch-map of Dam at Head of Pecos Canal.

a considerable volume of storage in the reservoir thus created. The dimensions of the dam were as follows: length on crest, 1050 feet; maximum height, 48 feet; outer slope of rock-fill, 1½ to 1; width of rock base, 106 feet; crown, 10 feet. The earth facing has also a crown width of 10 feet, making the total width 20 feet on top. The slope of the earth embankment that is built against the rock-fill is 3.5 to 1, which is covered with a revetment of loose stone 2 to 3 feet thick for wave protection. The rock-

fill before the addition of the earth facing is illustrated by Fig. 33, a view taken during construction. Fig. 34 is a view of the finished dam, taken in 1892. The grade of the main canal leading out from the dam on the east side of the valley is 10 feet above the base of the dam, and is excavated in limestone to a maximum depth of 38 feet. Fig. 35 is a view of the main canal and headgates, taken from the lower side.

FIG. 33.—LAKE AVALON DAM. ROCK-FILL IN PROCESS OF CONSTRUCTION.

The dam was in service until August 3, 1893, when it was ruptured by a flood-wave that was in excess of the spillway capacity, the maximum flood discharge being 42,500 sec.-feet. The water poured over its crest, and, as this style of dam is not calculated to withstand such an overflow, it speedily washed out a breach to the bed-rock over 300 feet in length. This was immediately repaired and built 5 feet higher, at a total cost of $86,000. The capacity of the open spillway at the west end of the dam was increased by widening it from 200 feet to a width of 240 feet, and by cutting it 3 feet deeper, making it begin to discharge while the water is 15 feet below the crest. A second spillway in rock was cut about half a mile to the west of spillway No. 1, having a length of 300 feet. In addition to these discharge-channels the main canal below the dam is so arranged that surplus water will begin to slop over its banks at a height of 13 feet above the bottom of the canal, over a length of about 200 feet. By opening the headgates and partially closing the secondary gates across the canal below, this slop-over can be given a large capacity of discharge. Ordinarily, however, the

water-level in this section of canal is maintained to a depth of over 20 feet above the floor of the canal by a series of thirty-one gates placed on the side of the canal, parallel to it, and across the spillway. These gates are hinged at the sides, and are each 5 feet ½ inch wide by 7 feet 2 inches high. They can be opened in an emergency almost instantly by the stroke of a

FIG. 34.—LAKE AVALON DAM, PECOS RIVER, NEW MEXICO. SHOWING THE CREST OF COMPLETED DAM AND SPILLWAY DISCHARGING.

hammer upon a latch-releasing bar at each gate, when the pressure forces them to fly open like a door. The opening can be closed above the gates by flash-boards, permitting the closing and latching of the doors. (See Fig. 36, taken from *Engineering News*, Sept. 17, 1896.) The total capacity which the spillways now have is estimated at 33,000 second-feet, while the water-level is still below the top of the dam.

The original cost of the dam was about $90,000, and the reconstruction was therefore but little less than the first cost.

Mr. H. H. Cloud, formerly of the Colorado Midland Railroad, was the chief engineer of the dam, with Mr. E. S. Nettleton acting as consulting engineer, and Mr. Louis D. Blauvelt as principal assistant. Mr. Cloud ascribes the cause of the overtopping of the dam to the fact that the spillways were choked by the débris from bridges, together with the bodies of drowned cattle brought down by the river. Another account states that the gate-keeper and his assistants were in Eddy at the time, indulging in a drunken spree, and did not start for the dam until the only bridges across

the river were washed away, and they could not cross. When they finally secured boats for crossing and reached the dam just before the disaster, they were unable to open the waste-gates because of a defect in construction, since remedied. It was believed that if the lateral waste-gates along the canal had been opened when the flood-wave first reached the dam, the relief thus afforded would have avoided the disaster. No loss of life was reported as a result of the flood, and but little property was damaged.

The reservoir capacity of Lake Avalon from the floor of the canal to the spillway-level is about 5578 acre-feet. When filled to the 23-foot level

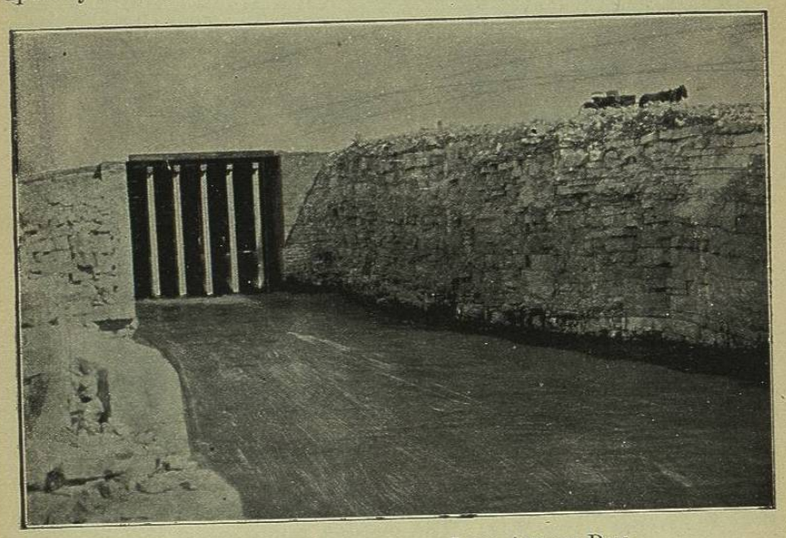

FIG. 35.—CANAL HEADGATES, LAKE AVALON DAM.

it had a length of about 5 miles and a maximum width of 1.5 miles. It submerged an area of 934 acres.

Water-tightness of Lake Avalon Dam.—The dam for some time after completion was apparently free from direct leakage through it, although water stood in a pool at the base of the dam, which was believed to come from springs, issuing from the rock. From the dam down for several miles there are springs of large volume coming out on the river-banks, whose total flow at the stone dam at Carlsbad, as measured by the writer in October, 1897, was approximately 90 second-feet. Since the construction of the reservoir these springs are said to be increasing in number and volume. The largest one, flowing 5 to 6 second-feet, broke out in a new place in 1896, some 3 miles below the dam. Distinct swirls and miniature maelstroms have been observed on the surface of both reser-

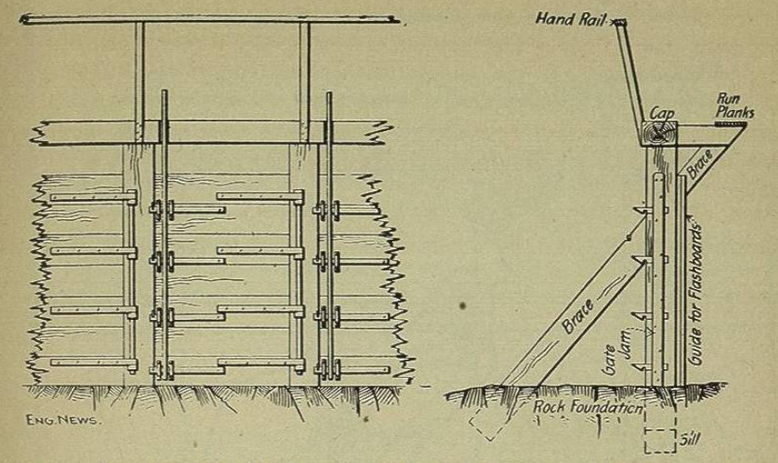

FIG. 36.—QUICK-OPENING GATES IN SPILLWAY OF LAKE AVALON RESERVOIR, PECOS VALLEY, N. M.

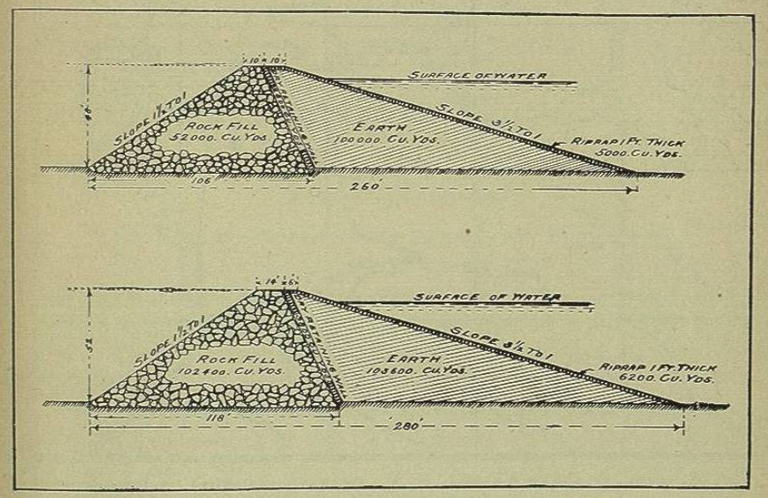

FIG. 37.—SECTIONS OF LAKE AVALON AND LAKE MCMILLAN ROCK-FILL AND EARTH DAMS, PECOS VALLEY, N. M.

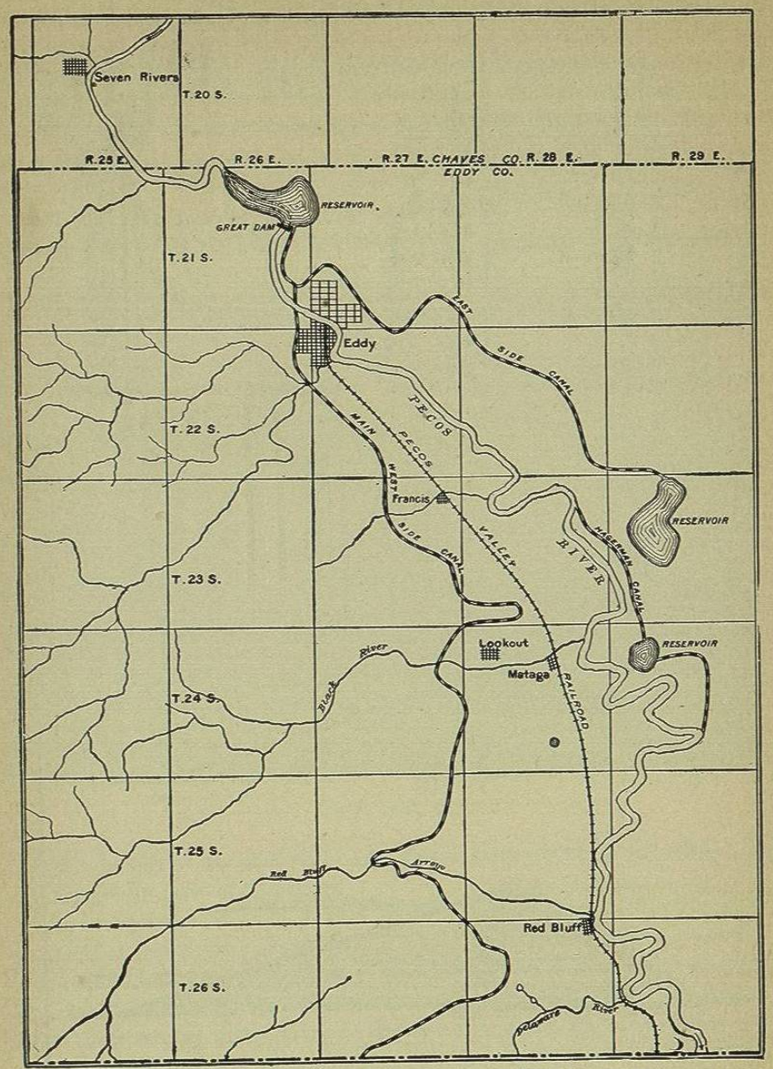

FIG. 38.—MAP OF PECOS VALLEY, N. M., SHOWING LOCATION OF RESERVOIRS AND CANALS.

voirs, from which it is surmised that water in considerable quantity is thus lost through the limestone formation, and that some of the springs are fed from this source, although many were in existence prior to the building of the dams.

This leakage did not apparently affect the stability of the dams, although it may have been the contributing cause of the second failure of Lake Avalon dam, which occurred at 11 P.M., Oct. 1, 1904. An account of this failure, prepared by E. C. Murphy, Assoc. M. Soc. C. E., for *Engineering News* (July 6, 1905), states that the dam failed by the water forcing a passage through the dam, and not by flowing over the top. He says: "There are two opinions as to the cause of the failure. One is that animals burrowed into the earth part of the down-stream side and

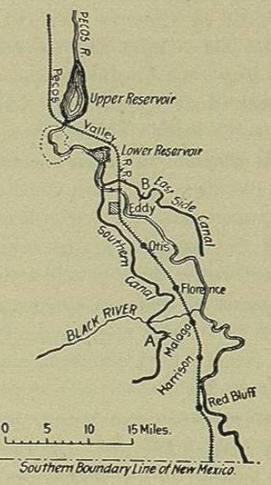

FIG. 39.—SKETCH-MAP OF PECOS VALLEY CANALS.

weakened the earth facing; the other is the failure occurred near the base at the right back, due to a faulty connection of the dam with the bank." The flood discharge at the time was estimated at 82,000 cubic feet per second.

After the partial destruction of the dam the entire irrigation project passed into the control of the United States Reclamation Service, and the Avalon dam, which was an indispensable link in the system, was reconstructed on the plans and under the supervision of Mr. B. M. Hall, M. Am. Soc. C. E., as engineer in charge. The old dam was increased in top width from 20 feet to 43 feet by a substantial addition to the earth-fill on the up-stream side, and a core-wall of concrete, heavily reinforced