

## SECT. II.—OTHER SELECTED PAPERS.

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(*Paper No. 3553.*)

“An Example of Irrigation in the Arid Regions of the  
United States.”

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THE irrigation of the arid land in the Far West, more especially in the Rocky Mountain States, presents a problem of such importance that the Government of the United States has taken the matter into its own hands, and has appointed engineers to report on various sites for reservoirs for regulating and controlling the flood-waters caused by the melting of the snow on the mountains in the spring. In the following Paper the Author presents a description of a typical irrigation-scheme which has been carried out by a private company, called the Wyoming Development Company.

*Location.*—The land included in this scheme surrounds and is tributary to the town of Wheatland, a handsome little town of about 1,000 inhabitants, situated on the Cheyenne and Northern Railroad, at an elevation of 4,700 feet above sea-level, and about 90 miles north of Cheyenne, an important station on the main line of the Union Pacific Railroad. The area of land which is expected ultimately to be reclaimed is about 60,000 acres, or nearly 100 square miles (Fig. 1, Plate 6).

The soil in the district is of excellent quality, being in most places several feet in thickness and comparatively free from that western nuisance, alkali. The herbage is comparatively abundant, being composed principally of range-grass, on which western cattle-herds feed. The country around is known as Wheatland Flats, and consists of a gently undulating tableland, generally sloping to the east and north, and at an average elevation of 5,000 feet above sea-level. The Laramie range of mountains, extending north and south along the western side of the land, forms a barrier against the cold weather which is experienced in most other parts of the State, and tends to render the climate more equable.

*General Scheme.*—Referring to Fig. 1, the general scheme is to tap the waters of the Laramie River at the point marked B,

and thence to use the natural waterways and excavated canals to deliver the water to the land. In Townships 21 and 22 N, and Range 73 W, a large reservoir has been formed by backing up the water of the Laramie River by means of a long earthen dam, situated at A. By means of this reservoir the flow of water down the river during the irrigation season can be controlled at will. The water flowing down the river from the reservoir is diverted at B by a crib-dam into a short canal, which discharges into a tunnel cut through a ridge intervening between the main river and the head of a gulch leading into Blue Grass Creek. The water, augmented by the flow of the creek, then flows on down to the Sybille Creek, where it is still further augmented. At C, on the Sybille Creek, the first canal starts; it is 34 miles in length, and conveys sufficient water to irrigate the southern and eastern parts of the land. About 6 miles farther down the river, at D, Canal No. 3 begins. This canal is 12 miles in length, and supplies the central part of the land, and, when occasion requires, Reservoir No. 1, which acts as a balancing-reservoir, is filled up from it. The last canal, No. 2, has its head-gates at E, and flows through the northern part of the land, passing also through the town of Wheatland. There are numerous laterals, of various sizes according to requirements, and there are also several sites for storage-reservoirs which can be used as the land becomes settled.

The great advantage which this scheme has over most others is that the loss of water by percolation before it reaches the land which it has to irrigate is reduced to a minimum. The water traverses natural waterways throughout the entire distance from A to the head-gates of Canal No. 1 (C), with the exception of a short length of tunnel at B; but the tunnel, being cut through solid rock, allows no loss by percolation.

The various engineering features of the scheme will be described in detail, starting from the highest point, namely, at Reservoir No. 2.

*Dam across Laramie River.*—This dam, situated at the point marked A in Fig. 1, Plate 6, was built in 1900 and 1901, and forms Reservoir No. 2. The details of this reservoir are illustrated in Figs. 2-5, Plate 6. The embankment is built of earth taken from borrow-pits by horse-scrapers or by grading-machine and carts. It is 8,000 feet in length, and 34 feet 6 inches in height at the highest point, and contains 344,000 cubic yards of earth. There is no core-wall, but, for a distance of nearly 1,200 feet across the river-bed, sheet-piles made of three 12-inch by 3-inch planks bolted together were driven to the bed-rock. The water-face was covered

with pitching consisting of large boulders, and an apron was afterwards added, extending 30 feet out from the base of the bank. The embankment was built up in thin layers, thoroughly tramped down by the teams going over the surface. The water-slope is 3 to 1, and the outer slope 2 to 1. The total quantity of pitching on the slopes and in the apron amounts to 16,000 cubic yards.

The flow of water is controlled by four sluice-gates, placed side by side, as shown in Figs. 5, Plate 6. The outlet-culverts and the gate-tower are built in ashlar with cement-mortar, and are very substantial, and the foundations are of cement-concrete. In order to prevent percolation along the culvert-walls, six bulkheads were constructed, projecting 6 feet on each side of the culverts (Figs. 5). The gates are corrugated-steel sliding panels, worked by hand-wheels from the top of the tower. The culverts are each 6 feet in width, with a semi-circular arch, the maximum height being 7 feet; the total length of each culvert is 125 feet, and the thickness of the arch is 2 feet. The gate-tower is 34 feet 6 inches in height, 22 feet 4 inches in width across the face, and 12 feet in depth, the masonry being 4 feet in thickness. The wing-walls, of masonry, project 17 feet, at an angle of  $30^\circ$  with the culverts.

Reservoir No. 2, when full, covers about 6,588 acres, being about 8 miles in length and about  $2\frac{1}{2}$  miles in width at the widest part. Having an average depth of about 18 feet, it will contain about 120,000 "acre-feet" of water, or about 32,670 million gallons. The term "acre-foot" is used to denote the amount of water required to cover an area of 1 acre to a depth of 1 foot. The storage of water commences in October, and continues through the winter till early spring, when it is needed for irrigation purposes. At the north end of the reservoir there is a depression which acts as a natural spill-way when the water in the reservoir rises to within 5 feet of the top of the embankment. The gate-keeper's or watchman's house lies near the north end of the dam, and is about 19 miles north of Lookout Station on the Union Pacific Railroad. From this station all cement, machinery, etc., had to be hauled by teams over the prairie, the roads being only wheel-tracks. The total cost of the embankment, land, outlet-culverts, etc., amounted to £24,121, or about 14s. 9d. per million gallons.

*Diversion of Water from Laramie River.*—During the irrigation season the water is let out into the channel of the river through the sluice-gates, and after flowing down to the point marked B in Fig. 1, Plate 6, it is diverted into a canal by a log-crib dam, 10 feet in height, 30 feet in width and about 150 feet in length. The

logs are laid about 8 feet apart, in layers, alternately across and along the dam, and spiked together, the interstices being filled with stone—in this case granite and schist from the tunnel. The schist makes a very watertight dam, as it weathers into a clayey mass when exposed to the atmosphere and to water. From this dam a channel, 19 feet in width at the bottom, with slopes of 1 to 1, and 1,400 feet in length, was cut to the entrance of the tunnel. The head-gates, four in number, are similar to those at Canal No. 1. The openings are 5 feet in width and 4 feet in height, the framing consists of timbers, 12 inches by 12 inches, and the boarding is 3 inches in thickness. No particular attention was paid to watertightness, cheapness in construction being the first consideration, and wood was used wherever possible, as lumber could be obtained in the mountains close at hand, and cement would have had to be hauled 40 miles from the railroad through the mountains, over a practically roadless country, besides involving a heavy charge for railroad freight. The fall of the channel is 4.6 feet per mile. The total cost of the crib-dam, head-gates and channel, was £1,517.

*Tunnel.*—The tunnel is cut through the “divide” between the Laramie River and a gulch which leads into Blue Grass Creek. It is 7 feet by 8 feet in cross-section and 3,100 feet in length. The excavation of this tunnel was very expensive and troublesome owing to the toughness of the rock. The contractor who started the work was made bankrupt by it, and the Company had to finish it themselves by day-work. Dynamite was first used, but proved unsatisfactory owing to the peculiar toughness of the rock, which was chiefly a black mica schist, and eventually “rackarock” was adopted with satisfactory results, after the construction of the tunnel had been several times almost abandoned. The drilling was all done by compressed-air drills, supplied with air from air-compressors driven by a temporary water-turbine installation. The water from the river having been diverted along the channel already referred to, and a tail-race having been cut for temporary use, a head of about 10 feet was available at the turbines. By using compressed air the tunnel could be driven from both ends at once, the air being conducted in wrought-iron pipes over the few hundred feet of hill separating the inlet and the outlet. Even with these facilities the cost of the tunnel was very high, amounting in places to as much as 50 dollars (£10 8s. 4d.) per foot run. With a gradient of 1 in 50 for the first 400 feet, and 1 in 100 for the remainder, and a total fall of 35 feet, the discharge from the tunnel was found to be 1,437 cubic feet per second when running

full. The total cost of the tunnel was £28,308, which gives an average cost of 3s. 3d. per cubic foot.

Referring to Fig. 1, Plate 6, it will be seen that the flow of water follows Blue Grass Creek, down the Sybille Creek, and thence to the point C, where the head-gates of Canal No. 1 are situated.

*Canal No. 1.*—The diversion-weir is framed in 12-inch by 8-inch uprights, spaced 8 feet apart and stiffened with 8-inch by 8-inch sloping struts on the downstream side; the upstream side is planked with 3-inch timber, and backed with earth. The head-gates are framed in 8-inch by 8-inch timbers, with six gates, 4 feet in width and 5 feet in height of opening, made of 3-inch planks. On the centre-post of each gate is bolted a rack, which, with the aid of a crowbar, serves for lifting the gate. The canal is 34 miles in length, and 25 feet in width at the bottom, with slopes of  $1\frac{1}{4}$  to 1, and, when running full, at a depth of 4 feet, its carrying capacity, as ascertained by measurement, is 427.56 cubic feet per second. This is the largest canal in the system, and will irrigate 38,000 acres. Its construction proved very expensive, some portions costing as much as £2,000 to £2,500 per mile. The gradient is 2.1 feet per mile at the commencement, and increases as the width of the canal decreases.

There are three siphons, crossing respectively under Dead Head Creek, Brush Creek, and Sand Creek. Originally the water was conveyed over these creeks in timber flumes, but these were washed out so often and so easily by freshets in the spring, that wooden pipe-siphons were eventually laid. These wooden pipes are similar in construction to a barrel, the staves being spruce planks, 8 inches by 2 inches, and the hoops of  $\frac{1}{2}$ -inch round iron spaced 6 inches to 8 inches apart according to the head, the ends fitting into shoes so fashioned that the hoops can be screwed tight (Figs. 7, Plate 6). The staves are planed to the curve of the pipe, and their edges to radii. These pipes are successfully used in the Rocky Mountain and Pacific States for water-power purposes, and are even used in some towns for domestic water-supply. The city of Denver, Colorado, has about 80 miles of wood-stave pipes, ranging between 24 inches and 48 inches in diameter, and carrying a head of water as high as 125 feet. The inlet to one of these siphons is illustrated in Figs. 6, Plate 6. At Deadhead Creek there are two 6-foot pipes, 165 feet in length, with a working head of 8 inches. At Sand Creek and Brush Creek there are three 4-foot pipes having approximately the same hydraulic gradient as those at Deadhead Creek. The length of pipe at Sand Creek is 200 feet, and at Brush Creek 165 feet. The total cost of Canal No. 1 was £30,000.

*Canal No. 2.*—About 10 miles below the starting-point of Canal No. 1, at the point marked E in Fig. 1, Plate 6, are situated the head-gates of Canal No. 2. There are four gates, each 4 feet in width and 5 feet in height of opening. This canal is used all the year round, as the water is required for stock-raising purposes in and around the town of Wheatland. It is 22 miles in length, and at the head-gates it is 19 feet in width at the bottom, with slopes of  $1\frac{1}{4}$  to 1, having a capacity, when flowing at a depth of  $3\frac{1}{2}$  feet and with a gradient of 2·3 feet per mile, of 340·67 cubic feet per second. This is sufficient to irrigate 20,000 acres.

The cost was comparatively small, owing to the canal being entirely in soil, no rock-cutting being required. The total cost was £7,285.

*Canal No. 3.*—This canal starts about 5 miles from Canal No. 1, at the point marked D (Fig. 1). It is the shortest of the three canals, being only 12 miles in length, and is only 15 feet in width on the bottom at the head-gates. There are three gates, each 4 feet in width and 5 feet in height of opening. The capacity of this canal is about 250 cubic feet per second, and the water is principally used for filling Reservoir No. 1. There is one siphon, crossing Brush Creek, consisting of one pipe, 4 feet in diameter and 200 feet in length. The total cost was £9,422.

*Reservoir No. 1.*—This reservoir was formed by running a small embankment, about 10 feet in height, along the outlet-side of a small lake. When full it has a surface-area of about 340 acres, and an average depth of 17 feet. The dam is 6 feet in width at the top, with inside and outside slopes of 3 to 1 and  $1\frac{1}{2}$  to 1 respectively. The reservoir is used as a distributing-reservoir, and is filled from Canal No. 3; if necessary it can also be fed from Canal No. 1. The total cost of the embankment, outlet-pipe, etc., was £1,875. There are several excellent reservoir-sites on the Company's land, which will be utilized as occasion demands.

*Laterals.*—The main laterals vary in width between 6 feet and 8 feet, and the gradients between 6 feet to the mile and 20 feet to the mile, the widths and gradients being governed by the area of the land to be irrigated and the natural gradients of the land. The laterals were generally made by means of ploughs and horse-scrapers, both of which are freely used in all excavation-work. The scrapers may be described as horse-drawn shovels of  $\frac{1}{2}$  cubic yard to 2 cubic yards capacity, the larger scrapers being used in the lighter soils.

*Distribution.*—The water is divided in *pro rata* shares among the different landholders, the minimum amount being at the rate of

1 cubic foot per second to every 80 acres. The widths of the division-weirs are proportioned according to the flow in the canal and the *pro rata* rate.

*Cost of Land.*—The price of land varies between 22½ dollars (£4 13s. 9d.) and more than 100 dollars (£20 16s. 8d.) per acre, with a perpetual water right, the amount depending upon the proximity of the land to the canals, railroad and town, and upon the quality of the soil. Ten years' time is allowed for payment, in equal annual instalments, with interest at the rate of 6 percent. No payment except interest has to be made in the second year, this arrangement giving the settler of limited means an opportunity of paying for his farm.

*Produce.*—The crops obtained are:—Wheat, barley and oats, 20 to 50 bushels to the acre; onions, 100 to 400 bushels to the acre; potatoes, 200 bushels to the acre. Small fruits such as raspberries, strawberries, etc., are easily cultivated, and cherries and plums are indigenous. Sugar-beets are easily raised, and if a factory were established near at hand a profitable industry could be established; in Colorado, where capital has been expended in sugar-beet factories, many farmers make good profits in raising beets alone. All classes of vegetables thrive in the soil under irrigation.

*Total Cost.*—The following is a summary of the total initial cost of the works described, exclusive of the small laterals:—

Reservoir No. 2 . . . . .	£ 24,121
Diversion-dam at tunnel . . . . .	382
Channel to tunnel . . . . .	1,135
Tunnel . . . . .	28,308
Canal No. 1 . . . . .	30,000
Canal No. 2 . . . . .	7,285
Canal No. 3 . . . . .	9,422
Reservoir No. 1 . . . . .	1,875
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	102,528

The Paper is accompanied by four tracings, from which Plate 6 has been prepared, and by seven photographs, which may be seen in the library of the Institution.

