Wheatland Industrial Co.........	33,115	45
Wyoming Land & Irrigation Co..	4,526	50

tion, the cost per acre of water rights, or of water for irrigation in the arid region, is far higher than is usually appreciated. During earlier decades, before any considerable number of large irrigation canals had been built, it was a relatively simple and inexpensive matter for farmers to join together and build small canals that could be enlarged as the demand for water increased. All such easily available opportunities, however, have been utilized, and development has proceeded to a point where on most of the recent irrigation systems it has been necessary to provide storage, thus adding materially to the cost.

There has also been a notable increase in the cost of labor and of materials used in construction. This condition has been pointed out in various hearings before Congress, notably in the series before the Ways and Means Committee of the House of Representatives at the time of the granting of the $20,000,000 loan. It is there shown, notably in a statement submitted by Representative Mondell, that one of the arguments for increase of the reclamation fund was in the fact that common labor had advanced from the time of the preparation of the plans for works in 1903 and 1904 from 20 to 50 per cent, and that the efficiency of such labor had fallen off in greater proportion. Costs were also affected by the increased price of materials and equipment.

The figures in Tables I, II and III obtained from printed reports of state engineers and public data, show that on over 90 modern irrigation systems being built by private or corporate capital, the cost per acre averages nearly $53. This cost does not include the annual cost for operation and maintenance.

The cost to the settler is increased by the fact that payment is made on most of these projects in instalments bearing interest at 6 per cent or even more. The total payments made for such a water right with simple interest at 6 per cent would be about $70.50 per acre on the basis of ten equal annual instalments of the principal as compared to $53 without interest.

For comparison with the cost of the foregoing private and Carey Act projects, there is given in Table III a partial list of the projects being built under the terms of the reclamation act showing the total acreages in them and the charges for water rights for completed portions of such projects as far as these have been fixed by public announcement of the Secretary of the Interior. These figures are seen to average a little over $41 per acre.

TABLE III.—RECLAMATION SERVICE PROJECTS.

State.	Project.	Approx. acreage.	Cost per acre. from	to
Arizona-California	Yuma	131,000	$55	$66
Idaho	Minidoka	118,700	22	30
Montana	Sun River	216,346	30	36
Montana-North Dakota	Lower Yellowstone	60,116	45	..
Nebraska	North Platte	129,270	45	55
Nevada	Truckee-Carson	206,000	22	30
New Mexico	Carlsbad	20,277	32	45
Oregon	Umatilla	25,000	60	70
Oregon	Klamath	72,000	30	..
South Dakota	Belle Fourche	100,000	30	35
Washington	Okanogan	9,900	65	..
Washington	Sunnyside	102,824	52	..
Washington	Tieton	34,613	93	..
Wyoming	Shoshone	164,122	45	50

[12]Estimated at from $75 to $200 per acre.
[13]Estimated at from $100 to $250 per acre, in-

It is interesting to note that the average cost of water from the Government works is about $12 per acre less than from the recent private works of comparable size. The real difference is still greater because of the fact that deferred payments on Government works do not draw interest.

This difference is further accentuated by the greater probability of the water users under the Government projects receiving an adequate water supply, as this matter has been given more careful consideration and deficiency guarded against with greater care than in the private investments. In fact, it is known that in a few cases at least there is not water enough for the entire area of land included in these projects. Also, on the Government works, provision in many cases has been made for drainage such as has not been provided by the private works, and the water is, as a rule, brought nearer to the land to be irrigated, still further reducing the cost to the water user.

Summing up all of these advantages—lower first cost, absence of interest, more dependable water supply, and more complete works, it would appear to be fair to state that water from the Governmenet projects is obtained at one-half to two-thirds the cost of that from private works here listed, including those built under the terms of the Carey Act.

RAILWAYS

Some Features of Double-Track Railroad Construction on the Chicago, Milwaukee and St. Paul Railway in South Dakota.

Contributed by F. W. Van Buskirk, Assistant Engineer, C., M. & St. P. Ry., Aberdeen, S. Dak.

The Chicago, Milwaukee & St. Paul Railway Company experienced such heavy passenger and freight traffic on its Hastings and Dakota Division, Minneapolis, Minn., to Aberdeen, S. Dak., in the years 1910 and 1911, that it was decided that the Division would warrant building a second track for the entire distance of 287 miles.

Early in the year 1912 the company placed several locating engineers in the field to determine the best and most economical location that could be had for the new line. As the original alinement was very unsatisfactory having a large number of sharp curves and steep grades containing a maximum curvature of 4° and a maximum grade of 1 per cent, it was found advisable, in order to handle future traffic more perfectly, to rectify the original grade and alignment in connection with the construction of second track. This meant that many miles would have to be constructed entirely new and some distance from the old alignment.

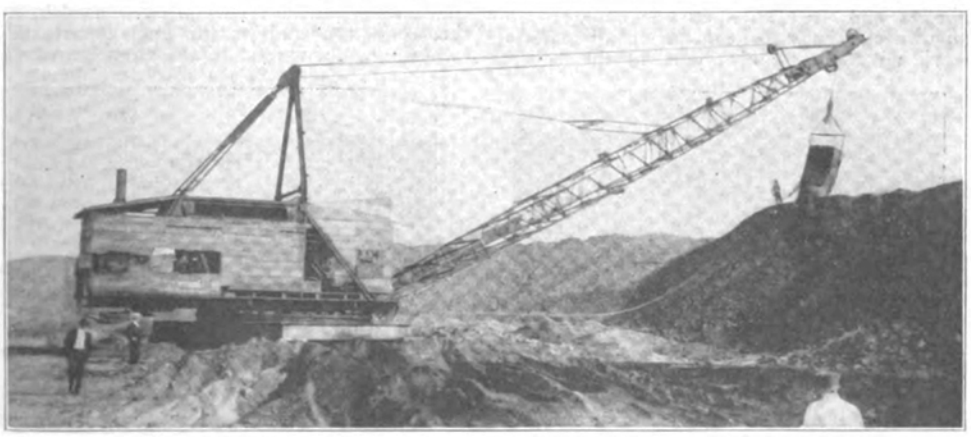

Fig. 1—Drag Line Excavator on Railroad Construction Handling 3½ Cu. Yds. of Fill Per Minute, from Side Borrow, with 100-ft. Boom.

Investigations resulted in finding a 0.4 per cent line practicable and it was adopted on the east division.

Montevideo, Minn., is a terminal point, being 133 miles west of Minneapolis and 154 miles east of Aberdeen, and it was desired to handle through business in both directions between Minneapolis and Montevideo, also between Montevideo and Aberdeen. For so few as four trains per day in one direction it was found an economy would result from the construction of a 0.4 per cent line.

There are a few places, however, where our ruling grade is a 0.5 per cent, which we could not hope to get away from, and by starting a train at its origin loaded to its limit for a 0.4 per cent grade would result in using a pusher engine in a few cases, but it was deemed unquestionable that it would be desirable to handle the through business independently of the local business in so far as possible.

Morris, Shepard & Dougherty, contractors of St. Paul, Minn., during the months of April, May, June, July and August, 1912, were granted contracts covering the construction of second track and rectification of present grade and alignment between Aberdeen and Summit, 75 miles, Twin Brooks to 4 miles east of Milan, 53 miles, Montevideo to Great Northern Crossing, 9 miles, Sacred Heart to Cologne, 79 miles, a total of 216 miles, involving about 7,440,000 cu. yds. of material to be moved, consisting of earth, loose rock and solid rock.

Probably the most interesting thing that could be said to the general contracting world in regard to the work performed by Morris, Shepard & Dougherty and to which attention is called as a remarkable piece of railroad construction, is a long fill about 5 miles in length averaging about 20 ft. in height, between Andover and Groton, S. D. This fill was all made to sub-grade for new double track from side borrow with drag line machines, inside of three months' time, moving a little more than 900,000 cu. yds. of material. There were five machines in service part of the time. The booms of these machines averaged a length of from 50 ft. to 100 ft. The highest yardage moved by one machine was 85,000 cu. yds., in one month, working two ten-hour shifts, or an average of 2.3 cu. yds. per minute of working time. A view of a drag line machine in operation is shown in Fig. 1.

John Marsch of Chicago was awarded in June, 1912, the contract covering the work between Summit and Twin Brooks, a distance of 15 miles, involving a yardage of nearly 890,000 cu. yds.

In June, 1912, the grading work from Hopkins, Minn., to Cologne, Minn., a distance of 22 miles, was let to the Cook Construction

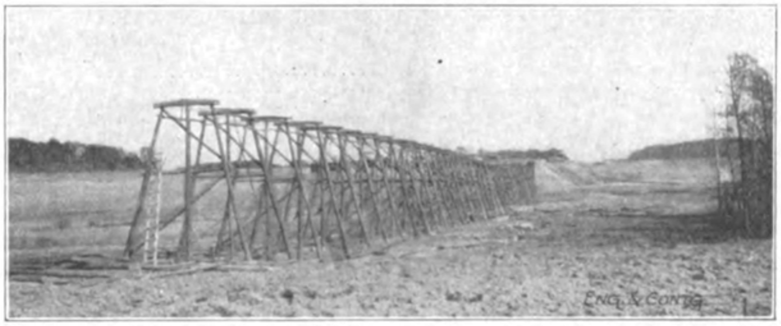

Fig. 2—Temporary Trestle for Railroad Grading in South Dakota.

Company of St. Paul. Of the 22 miles, 18 miles was entirely new work for new double track, averaging around 90,910 cu. yds. of material per mile, or a total of 2,000,000 cu. yds. This construction was quite difficult where the new change of line crossed Shady Oak Lake, about two miles west of Hopkins, Minn., the lake being about 1,200 ft. across where the new line was located, requiring a fill of 50 ft., 40 ft. of which was under water. As the contractor wanted to do the filling by first driving piles and then building trestle work up to the proposed grade so that he could have material hauled out over the trestle from an adjacent cut and side dump into the water, such action was undertaken. As the piles were being driven it was found that the water overlaid a very soft mucky material, there appearing to be scarcely any bottom to be found. Piles were spliced until the contractor finally succeeded in getting the false-work constructed so that the grading could be started. However, the operation did not continue long until the weight of the filling began to shove the piling out of place and the timber work settled so that grading operations had to be discontinued until more piling and trestle could be placed. It was finally decided to abandon further trestling and the work will be completed with the aid of scows or barges to carry the construction trains, the material being dumped on the head of the bank continuously, the dump being carried ahead instead of upwards. A view of trestle erected to fill from is shown in Fig. 2.

The following figures show the amount of work done and material used during the

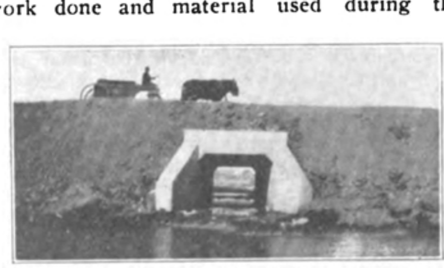

Fig. 3—Reinforced Concrete Box Culvert on C. M. & St. P. Ry., Near Summit, S. Dak.

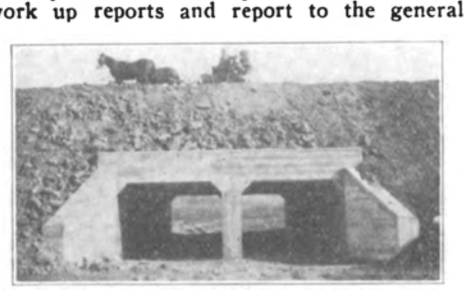

Fig. 4—Double Reinforced Concrete Box Culvert on Loop Line.

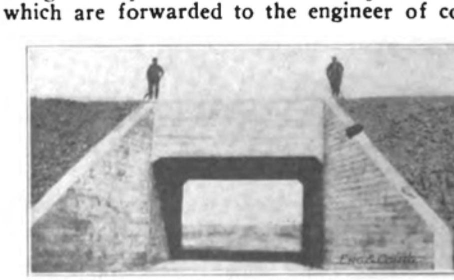

Fig. 5—Standard Reinforced Concrete Highway Under-Crossing on C. M. & St. P. Ry., in South Dakota.

year 1912: 6,034,560 cu. yds. of grading placed; 74,297 sq. ft. of concrete sidewalk and platforms; 41,215 sq. ft. of brick sidewalk and platforms, 35,532 bbls. Portland cement, 16,221 cu. yds. of crushed rock, 8,700 cu. yds. of sand and gravel, 188,700 paving brick, 1,149,000 lbs. of reinforcing material of concrete construction. Over $900,000 has been authorized to cover the cost of installing a complete signal system between Minneapolis and Aberdeen.

ORGANIZATION.

The work now in progress is divided into residences of from seven to twelve miles each, depending on the character of the work, a resident engineer having charge of the residency with a party of from four to eight men, all the resident engineers reporting direct to Mr. T. H. Strate, Construction Engineer, Aberdeen, S. D., who reports to Mr. A. G. Holt, Assistant Chief Engineer, Chicago, with Mr. C. F. Loweth of Chicago, Chief Engineer of the Milwaukee System. All construction work in general, under the construction engineer's supervision, is carried on with the co-operation of the operating department, which is represented by Mr. F. M. Melin, Superintendent of the H. & D. Division, headquarters, Aberdeen, S. D.

The construction engineer's office at Aberdeen is comprised of a force of from 16 to 20 men, with Mr. H. G. Crowe, Assistant Engineer, in charge of the drafting room; the writer, with assistants, having charge of all fiscal valuation and estimate work in connection with which all final estimates, actual cost data, and valuation of the various railroad properties when finally completed will be made to conform with the rules as prescribed by the Interstate Commerce Commission in their first revised issue, "Classification of Expenditures for Additions and Betterments for Steam Roads."

All concrete bridge construction is done by company forces divided into districts. Great Northern Tower is the dividing point, the work between Great Northern Tower and Hopkins being handled by one general concrete foreman, Mr. E. E. Chadwick, and from Great Northern Tower to Aberdeen by a general concrete foreman, Mr. F. M. Sloane. These two men are responsible for all bridge construction on their respective territories. All foremen in charge of the labor report to the general foreman, who reports to the construction engineer. Both general foremen are engineers and are furnished one engineer and an inspector each to keep tab on all material, work up reports and report to the general foreman any deficiency at any time during progress of the work.

Practically all construction work with the exception of grading is done by the company forces; the larger portion of right of way fencing, usually five-wire barbed for plain fence and eight-board snow fence, will be done by contract, having been awarded to Mr. H. S. Haggard of Chicago.

DRAINAGE.

Cast iron pipe, concrete pipe, and reinforced concrete bridges constitute the waterways used, and are very important and interesting parts of the work. Considerable time and money are required to get the proper surveys made so that decisions can be reached as to the proper kind and size of masonry structure required to properly care for all future needs and at the same time do it in the most economical way at time of construction. Views of standard reinforced concrete structures are shown in Figs. 3-7.

Drainage surveys of all waterways, from the smallest to the largest, are made by the resident engineers on their respective territories. The sizes of the drainage areas in acres are usually determined by a compass survey. Contours are taken at every 2-ft. interval from 200 to 800 ft. on each side of the proposed opening to properly determine the slope and course of the waterway. Soundings are taken at the proposed site to determine the kind of foundation to be used. Levels are run to locate high and low water levels and often various other detail field work is performed that will help to furnish the designing department sufficient information to design properly the most economical and practical structure.

All resident engineers are furnished drainage area sheets which when properly filled out by them gives the location, present structure, if any, height base of rail to bottom of opening under the track, unobstructed waterway in square feet, drainage area, per cent of slope, acres cultivated, acres in pasture, acres wooded, whether tillable or untillable, general character of soil, average fall of creek bed, high water in square feet due to head water, date of high water, head water above or below opening, back water above or below opening, number of feet water can be backed up without encroaching or damaging adjacent or private property, sketch of the situation and size of opening recommended, the size of the opening being arrived at by formula

$$A = C \sqrt[4]{a^3}$$

where A = size of opening; C average slope or constant slope a = area of water shed, the general conditions at each opening having considerable weight on the decision of size. The formula for waterway openings generally but not always determines the size of opening.

In the total distance of 287 miles between Minneapolis and Aberdeen there will be in the neighborhood of 175 bridges and concrete structures, including waterways, cattle passes, overhead highway, undergrade highway crossings, and something like 625 pipe culverts.

ESTIMATING ACTUAL COST.

Weekly progress reports are kept of all concrete work under construction. The actual amount of material and labor used in each bridge is reported on the final report sheets which are forwarded to the engineer of construction, in whose office the exact costs of material and labor are determined. A record of all freight on company material as well as all freight on contractors' supplies and equipment is being kept.

As soon as any piece of construction is authorized it is divided into "AFE" numbers, meaning "Authority for Expenditure," each number covering from 5 miles to 20 miles, depending upon the character of the work in order that the expense involved can be more readily and properly classified.

Estimates of costs of all contemplated improvements and often times comparative estimates for different propositions are made previous to securing authority from the management to proceed with construction. After formal authority is received and the work under way, then preliminary estimates are prepared covering each "AFE." This statement

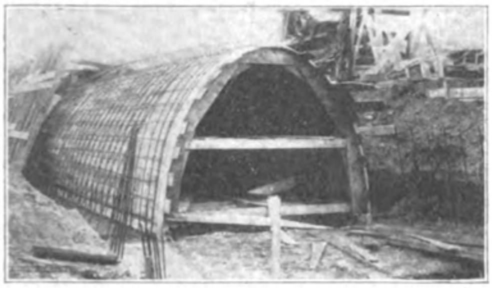

Fig. 6—Standard 12-ft. Reinforced Concrete Arch Culvert Under Construction, C. M. & St. P. Ry.

is supposed to be a very close estimate of the cost of the work, including every item of expense that is likely to be encountered, such as rail material, which is all 90-lb. steel on main tracks, freight on contractors' supplies and equipment, freight on all company material, rental of and repairs to equipment, etc.

All of these expenditures are itemized and the probable cost is distributed to conform as closely as possible to the Interstate Commerce Commission's prescribed method; that is, the costs are distributed between additional main track, grade reduction and change of line, sidings and spurs, temporary tracks, terminal yards, etc.

The object in making such preliminary statements is to furnish sufficient detail to enable the accounting department to classify intelligently the expenditures.

After the work on the various "AFEs" are entirely complete the actual cost of the various items, as near as can be obtained, will be collected for a final statement showing the correct distributions to the various accounts, accompanied with an estimate of cost covering all operating charges, renewal in kind charges, and everything that is pertinent and necessary for the accounting department to distribute properly the charges as they are sent in for final record.

As soon as a piece of masonry is fully completed the general concrete foreman in charge fills in the information called for in the "Masonry Cost Report blanks" which are furnished them, most of which can be taken from their time books and records. This gives the labor and material used from which the final costs of any piece of masonry is derived. Then a small sketch of each culvert and bridge structure is made, giving the conditions under which it was constructed, the "AFE" number, and the profile station, and quantities chargeable to each primary account are shown in the sheet. In this way close percentages of the distributive costs are arrived at and shown thereon.

The double track work between Minneapolis

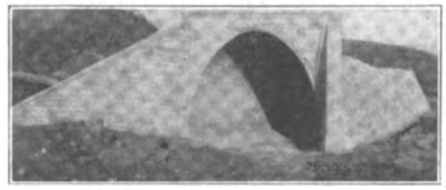

Fig. 7—Standard Reinforced Concrete Arch Culvert, C. M. & St. P. Ry.

and Aberdeen will in all probability be completed in the fall of 1913 when the company will have a first-class double track roadbed from Chicago to Aberdeen, a distance of 708 miles, and a single track from Aberdeen to Seattle, Wash., and will be in condition with first class rolling stock now in service, to handle the developing traffic from the lines west of the Missouri River and the new countries which are constantly being opened and settled in the west.

RIVERS AND HARBORS

A Discussion of Levee Location, Height and Grade.

Two useful tables and an instructive discussion of the proper location, height and grade of levees are contained in the report

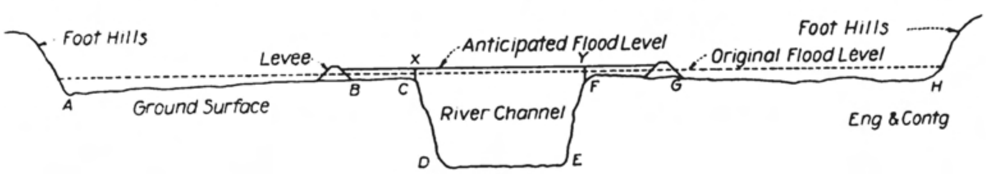

Fig. 1—Ideal Cross-Section of Overflowed River Valley.

(Illustrates characteristic ground surface slope, determination of hydraulic capacity of flood way, resulting flood level and position of levees.)

of Mr. Arthur A. Stiles, State Levee and Drainage Commissioner of Texas, which has just been issued. We abstract portions of the discussion and republish the tables here.

It is a well-known characteristic of overflowed river valleys that the ground surface, rising gradually from the base of the foothills at either side of the flood-plain, reaches its greatest elevation at the banks of the channel overlooking the principle stream. Hence, a levee to be of minimum height and maximum protection should be built along this crest, but a stable position cannot be obtained so near the channel, and the distance which should separate the proposed levee from the adjacent stream bank may be regarded as the result of a compromise between practical interests, and other more technical requirements, now to be discussed.

The case is selected for illustration where a protection levee is required upon each of the opposite sides of the stream channel. As a first requirement, obviously a flood-way or clear space large enough to convey the entire flood volume, must be provided between the opposite levees. The fixed factor of this flood-way is the maximum discharge of the stream, during the highest flood against which the proposed levees are designed as a protection. The adjustable factors are the heights and positions of the proposed levees, or the two dimensions sought. It follows conversely that the maximum discharge of the stream divided by the mean velocity of the flood, gives the cross-sectional area of the required flood-way. The area of the cross-section of the channel being established by Nature, it remains to increase or diminish the heights of the opposite levees, and the distance between them, until the proper supplemental area in the flood-way cross-section is found.

The simplest manner of finding this area is by a series of computations, using trial positions and heights for the levees. For this purpose a cross-section of the proposed flood-way may be considered at any point desired. As represented in Fig. 1, the anticipated flood level is the surface of the maximum flood, raised somewhat by reason of the levees. A trial elevation of this flood level with a trial distance separating the opposite levees, is assumed. Not being uniform throughout, the cross-section must be treated in three sections. The middle section represents the stream channel; the two end sections, *BC* and *FG*, represent the spaces between the channel banks and the levees. Usually, there is no reason to know with safe accuracy the actual mean velocity of each of the three sections. The separate mean velocities must, therefore, be theoretically calculated by applying Kutter's Formula, as previous explained. The wetted perimeter of the channel cross-section is the line *CDEF;* that of the end sections is the ground surface, *BC* and *FG*, and the submerged sides of the levees. The vertical distances, *CX* and *FY*, from the channel banks to the flood surface are not counted as part of the wetted perimeter. The hydraulic slope s and the coefficient of roughness n are the same for all parts of the cross-section.

Having computed the mean velocity and maximum discharge of each section of the cross-section, the total maximum discharge through the entire cross-section is obtained by adding these three results. Comparing this maximum discharge with the known maximum discharge of the stream, the area of the cross-section with the assumed positions and heights of the levees is shown to be correct, or too great or too small. If not correct, another trial computation is made with the assumed values changed in the direction last indicated, and the correct dimensions are soon found.

It will be noticed that an increase of a few inches in the elevation of the high-water level in the flood-way is equivalent to an increase of a hundred feet or more in the distance between the levees and the channel banks. But great care must be exercised in raising this level. The "regimen," or usual system of the stream, changes as the flood level rises. Sudden and disastrous alterations may take place in the channel; or existing levees further upstream may be overtopped by the resulting backwater.

The space required for a properly formed and located borrow pit is dependent upon the size of the levee that is to be built. As the earth must be taken only from the side of the levee adjacent to the stream channel, the

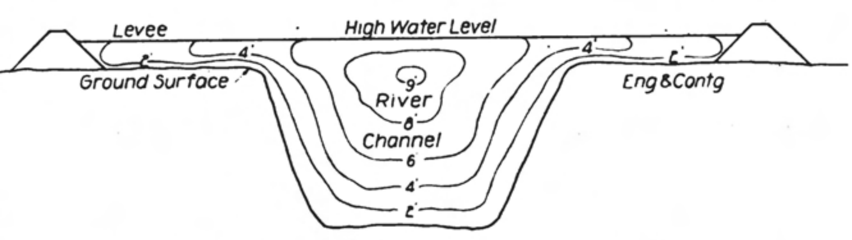

Fig. 2—Typical Cross-Section of River Channel, Showing Probable Distribution of Current Velocities in Feet Per Second and Their Influence Upon Levee Positions.