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NAVAJO

Leupp

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U.S. Indian Service Irrigation

THE LEUPP RESERVOIR & IRRIGATION PROJECT

NAVAJO EXTENSION, ARIZONA

Report of

[illegible signature]

Nov. 1908 Superintendent of Irrigation

THE LEUPP RESERVOIR AND IRRIGATION PROJECT.

NAVAJO EXTENSION, ARIZONA.

REPORT OF H. F. ROBINSON

Superintendent of Irrigation.

NOVEMBER 1908.

I N D E X .

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SUPERINTENDENT OF IRRIGATION.

DEPARTMENT OF THE INTERIOR,

UNITED STATES INDIAN SERVICE,

Albuquerque, N. M. November 23, 1908.

W. H. Code, Chief Engineer,
522 Bumiller Building,
Los Angeles, Cal.

Dear Sir:

On taking charge of the work of this district last spring I found in the office files specific directions to make the necessary surveys and investigations for a storage reservoir near the new school at Leupp, Arizona, to store waters of Canyon Diablo, and use them for the irrigation of lands lying in the valley of the Little Colorado river, in what is known as the Navajo Extension.

I personally looked over the proposition and deemed it of sufficient importance to warrant a complete topographical survey, so with your approval, I put a plane-table party in the field under Asst. Eng. R. G. Bush, who made a survey of the reservoir site, making a map with two feet contours in the reservoir and with five feet contours of the land lying under the reservoir, and along the river as far down as Tolchaco, nine miles below. I now make report on the project.

THE RESERVATION. The Navajo Extension lies in Northern Arizona, and includes Townships 21-22-23-24 north and Ranges 12-12½-13-14 and a part of 15 East, G. & S. R. B. & M., all unsurveyed land excepting the part in Range 15. It is the southern part of what is known as the Painted Desert, and is entirely arid and untimbered.

It lies at an elevation of from 4500 to 6000 feet. The greater portion being between 4800 and 5000 feet. It is practically unwatered with the exception of the Little Colorado River which crosses it from the southeast to the northwest corners. This stream has a shallow, sandy bed, carrying water about nine months in the year, often torrential in character. The balance of the year it is entirely dry. Canyon Diablo with its drainage enters the Little Colorado about the center of the Reservation. Its characteristics are described under another head. With this exception there is practically no water or watering places on the Reservation. The agency and school at Leupp, and a trader and Mission at Tolchaco, a trader at Canyon Diablo and the railroad agent and section men at the latter place and at Sunshine, are the only inhabitants of this area excepting the nomadic Navajo Indians, of whom there are about 450 on this reservation proper and a number off the reservation to the east.

They are entirely dependent on their flocks, and while they would do some agricultural work if they had a chance, there is no place on the entire reservation where they can, with their limited number and lack of means, get water on the lands.

The rainfall is slight; probably not to exceed 8 inches per annum. The records of Holbrook, on the Little Colorado and about fifty miles east of Leupp, will be about the same as would records kept at the latter place.

DRAINAGE AREA. Neither the Little Colorado nor Canyon Diablo are living streams the entire year. The former is dry at this point from two to four months each year, while the Canyon is dry seven or eight months of the twelve.

I have not been able to ascertain with certainty the drainage area of the Canyon. The entire east slopes of the San Francisco mountains and all of the country on the south to Chaves and Sunset Pass, also drains into the various tributary canyons. (See map)

From the maps of the U. S. Geological Survey, the drainage area to the tops of all of the divides show about 1550 square miles, but this includes the drainage of Mormon Lake, which I understand has no outlet, and the drainage of River de Flag, the drainage of which is cut off by a dam and reservoir near Flagstaff. Omitting this area, which is in doubt, we still have about 1220 square miles.

The drainage is effected by Locust and Walnut Canyons, which, coming together from the west, forms what is known as the San Francisco Wash; Canyon Diablo and Canyon Padre, from the south, all forming a junction some miles above the reservoir site.

Below this point of junction the Canyon is about 250 feet deep with precipitous sides, about 600 feet wide on the top and a maximum width of a couple of hundred on the bottom.

WATER SUPPLY, RAINFALL AND RUNOFF. The drainage area of this reservoir site lies almost entirely above the 5000 foot contour; 75 to 80% above 6000 feet, while the highest point reached is the top of the San Francisco Mts., an elevation of 12794 feet.

The only rainfall data on the water-shed is that of Flagstaff - though we have that of Holbrook about 50 miles east of the Reservoir site and on the "desert", at an elevation of about 5000 feet.

The highest flow line of Canyon Diablo is well defined by drift wood at about elevation 518. At the dam site, the present main channel is about 140 feet wide and 8 to 9 feet deep. On the west side is an alluvial deposit that has growths on that would indicate 20 years or more since it was disturbed. All drift found at the elevation of 518 to 512 is old, dry and weather worn, but what has occurred before is liable to occur again. At a narrow point in the channel above the dam site, the cross section is about 2900 square feet, the fall of the canyon is about 3 feet per mile. This would give a velocity of about 5.78 and a discharge of 15606 second feet, using N = .030

The Weather Bureau furnish the records of rainfall at Flagstaff from Oct. 1899 to Dec. 1905. During that time the annual rainfall was as follows:

1899		19.32
1900		16.57
1901		21.48
1902		25.86
1903		25.05
1904		20.07
1905		34.53
	Mean	22.56

The monthly means have been as follows:

January	1.69
February	2.92
March	2.53
April	1.55
May	1.25

June	.57
July	2.20
August	3.63
September	2.07
October	1.23
November	2.22
December	.70

The average annual precipitation is 22.56 inches, divided as follows: Spring, 5.33 inches; summer, 6.44 inches; autumn, 5.52 inches, and winter, 5.31 inches. The greatest monthly precipitation was 8.77 inches, in August, 1904, and the greatest amount of precipitation recorded in any 24 consecutive hours was 2.95 inches, on March 31 and April 1, 1903. The average seasonal snowfall is 87 inches. The greatest amount of snowfall recorded in any 24 consecutive hours was 24 inches, on February 1-2, 1901. Snow has been known to fall in every month of the year, except July and August.

The records from Holbrook, while entirely out of the drainage area are given, as they will probably be approximately what the precipitation is on the land that is to be irrigated from this reservoir, if built.

The records of the Weather Bureau are from 1888 to 1900 inclusive and from 1904 to 1908.

The total annual rainfall has been as follows:

1888	10.82
1889	7.60
1890	12.34
1891	6.76
1892	5.57
1893	7.76
1894	6.23
1895	10.39
1896	7.01
1897	7.20

1898	8.21
1899	4.58
1904	5.20
1905	17.63
1906	8.72
1907	15.16
Mean	8.69

The monthly means have been as follows:

January	0.77
February	0.67
March	0.69
April	0.52
May	0.31
June	0.14
July	1.38
August	1.42
September	0.75
October	0.65
November	0.93
December	0.63

The greatest monthly precipitation was in March 1905 when there was 2.98 inches of rainfall.

I have no record of the heaviest single precipitation.

To approximate the amount of water discharged through the canyon and which will be available for this reservoir, we may assume that the maximum flood was caused by the heaviest rainfall of record.

This maximum rainfall was 2.95" for 24 consecutive hours, which is 81.5 cubic feet per second per square mile. (Using 1220 sq. miles as drainage area).

The maximum discharge of the canyon as shown above was 15,606 second feet, or 12.79 second feet per square mile of drainage. This would indicate that the runoff is 15.6% of the rainfall. From figures made on the Zuni drainage by Supt. Harper and Mr. Schuyler, the maximum runoff per square mile was

21.6 cu. ft. per second, and the next larger flood gave 14.7 cu. ft. per second. The drainage area of the Zuni Reservoir is not more than one-half that of the Leupp Reservoir, and the smaller the drainage area the quicker the runoff occurs and the maximum crest is greater.

Taking the average rainfall, 22.56" and the runoff as 15%, the total runoff for the year would be 220,170 acre feet approximately.

Taking the minimum rainfall recorded, 16.57", and the same percentage, the total runoff would amount to 161,722 acre feet. The first would fill the reservoir to the 37 ft. contour nearly 19 times during the year, assuming the rains came at the proper times, and the latter, a little less than 14 times.

Of course, this is making considerable assumptions of conditions, for the rainfall over considerable of the area will be much less, and the runoff percentage smaller, though on the mountains both will be greater.

Assuming the total area to be irrigated to be 8000 acres, and the amount of water necessary to be 3.5 acre feet; the capacity of the reservoir at the 37 foot contour is 11,617 acre feet; the amount of water to serve the 8000 acres is 28,000 acre feet, or 2.4 times the capacity of the reservoir. These figures will give a factor of safety of almost 6 with the minimum rainfall recorded, which should make it safe. The fact that while the rainfall is evenly distributed, the runoff may not be, the greater absorbtion and evaporation of the summer making the supply smaller at that season.

In this connection I copy a letter from Mr. J. E. Maxwell Superintendent in charge at Leupp, regarding his observations of the flow of the Canyon.

Leupp Training School,
Leupp, Arizona Nov. 5th 1908.

Mr. H. F. Robinson,
Superintendent of Irrigation,
Albuquerque, N. M.

Sir:-

I have your letter of recent date requesting a statement as to the amount of water that flows through the San Francisco wash at the proposed site of the Leupp reservoir.

I have resided in this community for four years and have had opportunity, during that time to observe the amount of water that has flowed through the wash. Most of the water comes in the spring or late in the winter. Part of this time the stream flows a torrent but for several weeks, varying from three to six weeks, it flows a stream about 40 feet wide and from 2 feet to 4 feet deep.

There is sometimes a flow of water in the late summer that will last for a week or sometimes two weeks. This flow generally begins with a torrent and gradually subsides until it entirely ceases. Another flow sometimes occurs in November or December and continues for about the same length of time.

These later flows do not always come but the spring flows have not failed for many years.

I have had no instrument to measure this water, nor have I even kept a record of the different stages and the height of the water at each stage. I am of the opinion, however, that there is sufficient water flows through the wash at this point to fill the proposed reservoir at least once each year.

Hoping that this letter will be of service to you, I am

Very respectfully,

Joseph E. Maxwell

Superintendent.

Mr. Maxwell's observations will not bear out the assumption of rainfall and runoff made above, as they are simply from casual visits, and their value is to be taken in connection with any other facts that may be available.

Should we assume that the average rainfall is the mean between that of Flagstaff and that of Holbrook, we find that this mean is 15.62", or very near the minimum figured above from the Flagstaff records. The mean of the minimum of the two places is 10.88 or just 65% of the minimum figured above.

Should this all come during the winter and spring, of course most of it would be wasted for lack of use and storage capacity.

SILT. Notwithstanding the large drainage area, I am informed that very little silt is carried by this wash. With the water taken from the reservoir at the 16 foot contour, there will be quite a large capacity below this contour for the accumulation of the small amount that may be brought down.

RESERVOIR. The reservoir is in 35° 17' North Latitude and the 111° meridian passes through it. It lies about 1½ miles from the school and agency at Leupp, on the Navajo extension, and 12 miles from the A. T. and S. F. Ry. at Sunshine, Arizona.

There are six requirements for a reservoir storage project, viz:

1. Sufficient water supply.
2. A good basin.
3. Good dam site.
4. Good foundation for dam.
5. Good materials at hand for construction.
6. Sufficient good land.

The water supply has already been discussed under a separate heading.

The second - a good basin. In the present case the canyon widens out suddenly into a basin. (See map). The south and west walls are cliffs of red sand stone lying on a bastard lime stone. The north and east sides are rolling hills of gravel and earth lying on red sand stone.

The basin is not complete, for on the north side are five openings in the hills, across which it will be necessary to build earthen dykes, to raise them to el. 542. With this done, the water can be raised 37 feet above the bedrock at the dam site.

Third. Dam site. The dam site is fairly well adapted for the purpose, though not an ideal site.

The side walls are of red sand stone, shaly on the outside, but at a depth of a couple of feet are hard. The east side rests on the lime stone, fully exposed, which extends across a portion of the canyon bottom. The distance between the walls is about 516 feet at the bottom and at el. 541 is 760 feet.

Fourth. It is proposed to build the dam on this limestone ledge. The west side of the canyon bottom is of earth. Test pits were sunk to determine if the limestone extended across on the same level, and these pits were sunk 18 feet, or eight feet lower than the exposed ledge without finding rock. It was impossible to dig deeper without rigging a well digging outfit and curbing the pit, and Mr. Bush finished the other work and left without going deeper. The rock probably is there within a few feet, as it is exposed above and below the dam site entirely across the channel, though it is problematical.

But assuming that it is a soft bottom, the type of dam recommended as good construction at this site, can be built on a soft bottom.

Fifth. As the type of dam selected is of reinforced concrete, the material needed is gravel or broken stone, sand and the reinforcing steel. The limestone crops out and can be easily quarried within 300 feet of the dam, and with a rock crusher will make the best of broken stone and sand. Gravel is not to be had near, and the sand is both fine and dirty. Water can also be gotten without excessive cost, and probably the easiest way would be to pipe it from the water tank at Leupp, about 1½ mile. The pump at Leupp is ample to supply both the school and any plant that would be erected at this point.

Sixth. Sufficient good lands. This question will be discussed later.

TYPE OF DAM. The type of dam that I believe to be the best to use at this point is a reinforced concrete dam of the gravity type, and particularly the type that is exploited by the Ambursen Hydraulic Construction Company. My interest in this is purely from an engineering standpoint. With this type, we secure a maximum of strength and stability with a minimum of material. This is an object when construction is being done at some distance from the base of supplies.

To avoid taking up time and space in a description of this type, I enclose printed matter covering same.

Buttressed Dams of the gravity type are also discussed by R. C. Beardsley in Eng. News, Vol.59, No.17, p.452. April 23, 1908.

The type of construction suggested (see drawing), is of the rollway type. The crest to be at elevation 537, length of rollway 456 feet, total length over all 760 feet, although 124 feet of this length amounts to very little. The details of construction are shown very plainly on the drawing.

DETAIL OF DAM. For details of the construction of the proposed dam, I have consulted with the Ambursen Hydraulic Construction Company, and I herewith give a copy of their letter and estimate in the matter which seems to cover every point and detail necessary.

Boston, Sept. 15, 1908.

Mr. H. F. Robinson,

Supt. of Irrigation, U.S. Indian Service,

Blackrock, New Mexico.

Dear Sir:-

We are sending you under another cover preliminary design for the Leupp dam. I need not call your attention to the fact that while the information you have given us is unusually complete and clear, yet we are at a disadvantage in not having been on the ground. You will therefore appreciate that there may be many points of design and many items of estimate which would be changed when we had actually inspected the site and worked over the problem with you. I therefore find it necessary to make a number of comments as follows.

We accept your suggestion that the portion of the dam over the earth deposit should be made with a floor. A great deal however depends upon just what the nature of that earth deposit is. We have assumed that in any case it is excavated down to the level of the rock in the river channel. Possibly by the time we have got down to that point it may prove to have some sustaining character of its own. In fact although we have built one or two dams on sand and on clay, we have never yet found a case which called for piling, as we were always able to spread the floor sufficiently to get a load of from 1.2 to 1.5 tons per square foot. It is a pretty poor foundation that will not carry this with safety. If the material is anything at all in the nature of gravel or clay it would carry this load without any further provision. If, however, it is a strict alluvial deposit the case may be quite different as some alluviums will compress like a feather bed. You see therefore that we are quite in the dark on this important point.

If, however, the alluvium is so bad as to be unable to carry the load and yet rock was to be obtained at any reasonable depth, say 30 ft. or 40 ft. below the grade of the channel, then we have a special method of sinking walls or piers, of which we have secured control from one of the leading engineers in the country making a specialty of difficult foundations. By this method we can at very moderate cost and with very little excavation sink a cut-off wall clear down to the bed rock and at a very low cost per yard. We would sink one of these walls under each buttress which would of course be a virtual extension of the buttress to the bed rock. We would use the same method to sink a cut-off wall to bed rock and probably a second one at the down stream toe of the dam. This particular method I cannot describe now as we have not yet prepared our literature on it, but it enables us to enormously cut down the cost of such work over the old methods.

If there is no rock bottom to be reached the same method enables us to sink either walls or piers under each buttress to such a depth and of such dimensions that they act as adequate piles to carry the computed load. The possession of these features enabling us to overcome the difficulties of this class of work makes our type of construction peculiarly adapted to your conditions. I will refer to this again in the estimate.

The section on the rock would terminate at the toe as shown in the drawing. The section on the soft foundation would probably be extended so as to form a long tumbling hearth for a sufficient depth below the dam to safely take care of the plunge of the water and receive the standing wave. We should probably extend it at least 30' below the dam. This apron is filled with reinforcement so it cannot break under the action of the water.

There are a lot of other variations which might be introduced when we have inspected the conditions. You might wish for instance to alter the pitch of the upstream deck; to produce a more vertical resultant on certain classes of foundation. All this however cannot be discussed in a preliminary way and would not have any very great, if any, effect on the cost.

I enclose our preliminary estimate sheet. In this estimate I have taken account of the fact that you work under an eight hour day and have assumed moreover that the Indian labor amounts the same in efficiency as white labor at $2.50. I am free to say that if we undertake the work I think we would be able to send out a large force of Italian laborers at no more than $2.00. We use great numbers of Italians who as a rule stay with us and move from job to job, who receive in the east $1.75 a day, and who will be very glad to go to the far west for 25 cents additional. I believe however it is the policy of the government to employ the Indians so far as possible. I therefore make this suggestion for what it is worth at this time.

I will comment on the estimate quite fully by numbers.

(2) Your climate may permit of the use of tents and considerably reduce that item.

(3) We have enlarged this item somewhat on account of the high price of lumber and timber for bins, towers, etc.

(5) This item is only the ordinary cost of a cut-off wall when the foundation is in fairly impervious gravel. If we have to sink a cut-off wall to the rock by the process above alluded to, it of course will introduce an additional item but not nearly as large a one as you might imagine. By the special process which we have, the cut-off wall need not bemore than 12" thick and well reinforced. It is simply a water barrier and has no relation to the principal structure of the dam.

(6) This item covers the excavation down to the grade of the river bed. This is all the excavation there would be, as if we had to go to bed rock we should use the special process above alluded to which requires no excavation.

(7) This merely relates to the preparation of the footings for the buttresses where they rest on rock. Of course the precise nature of the rock surface is not known by us but the item is a small one anyway.

(8) This item and all other items involving labor are abnormally high as compared with our cost records here, due to the eight hour day and the high price of labor.

(9) I thought it safer to assume that we might have to crush our sand out of the rock.

(13) In the east this item would not run over $1.80 but I think the figure used is safer under your conditions of labor.

(16) I have assumed eight months as the time of completion of the work, on the further assumption that the alluvial deposit excavated to grade will carry the structure without further preparation. Would say however that we ought to beat this time a month or more if your weather conditions are stable at the time the work is undertaken. Of course I cannot judge how long it would take to put down the sub-foundations to rock until we know the depth of the rock and the grade of the over-lay. The process above referred to however is nearly as rapid as pile driving so that the extra time would not be a serious item.

(7a) We have several designs for gates which have worked out excellently in practice and which enable all the handling of the gates to be done from inside the dam, while at the same time decreasing the cost. The general idea of this gate is shown on page 29 of the Ellsworth booklet which we sent you. The gates may be handled by hydraulic pressure, motor drive or hand power. The latter I presume would be employed in your case on account of the fluctuations of level and the comparatively low heights of dam. We generally like to put in a number of small gates as it gives us a better graduation of the flow for irrigation work which I assume is the purpose of this dam.

(10a) You did not say whether the cost of $4.50 per ton for coal includes the haul or not. I have assumed that it does and our estimate is made accordingly.

(13a) In this item I have allowed a rough sum of $5000 for wooden sheet piling if the character of the soil proves that this would answer the purpose. If it was better to use the concrete wall this item would disappear and the concrete wall be substituted at not very much, if any, greater cost.

(14a) We shall probably not use log piling anyway but I have left this entire item out having commented on it above, as there is no use figuring on it until we know precisely the conditions.

(15a) It may be that the government is already the owner of abundant plant for this class of work. If so this item would disappear. Otherwise it would remain to cover the depreciation on the plant in executing the work.

(17a) We get our insurance at a very low rate, namely 2% on the pay roll. I do not know whether the government insures its labor or not but I have at least allowed the item. The government can take advantage of this special rate of ours if they wish.

(22a) I have allowed liberally for contingencies, this being an item that usually absorbs all the unknown quantities. Our cost accounts, - which by the way we think are kept in better shape than any other concern in the country, - show that thus far we have very rarely trenched upon our contingency item to any very considerable extent.

Our own commission of 15% is the regular charge which we get on all our work.

The sum total seems to indicate that the cost of the work will run out at about $180,000. We have been extraordinarily successful in our estimates, as witness the enclosed sheet covering a group of seventeen of our jobs finished last year. We have done even better this year. Please understand however that the present estimate is a preliminary and we would not wish to make a final estimate until we had thoroughly been over the work on the ground.

You will note that our estimate is itemized very fully and it is my belief that it covers everything in this case as described by you, excepting the sub-foundation work necessary when the nature of the alluvial over-lay is discovered. I would add moreover that if we find we sink each buttress clear down to the rock by the process above alluded to, this will do away with the necessity of a floor and so far as concrete is concerned the one item will approximately balance the other, leaving only the labor which is not a large item.

We do not usually make a practice of sending out our estimate sheets as you can recognize that this is information of a very intimate and confidential character. We however do so with pleasure in your case as our lack of precise knowledge makes it necessary that you should observe the lines along which we have estimated and draw your own conclusions whether we have varied materially from the facts. You are quite at liberty to show this estimate to any of your associates but I will merely ask that you otherwise keep it confidential as against parties who might be our competitors.

This job is one of very particular interest to us in view of the nature of the foundations. We should make a most conspicuous success in attacking the problem you have presented as our experience along these lines has probably not been enjoyed by any other concern in like business. We have now built forty-one dams and very many of these have been on foundations of treacherous character, - and it is needless to say every one has been a pronounced engineering success.

I do not know the next procedure to get closer to this work. If the matter is referred back to Washington I would be glad to go down at any time and meet the Department there for discussion.

If on the other hand the matter is determined on the ground the proper step would be for our general superintendent to come out on an appointment and go over the whole matter carefully with you. Very possibly this ought to be done anyway before we saw the Washington authorities.

In private work we have been accustomed to charge our actual travelling expenses on inspection trips of this character with no charge for time. The amount of inspection work which we do in the course of a year runs up a very formidable bill for travelling expenses, which we have for a year or two back assessed on each party served, to the satisfaction of all. If however there is anything in the government regulations which precludes this payment of travelling expenses we will waive the matter.

As stated in a former letter I understand that our business methods coincide exactly with the requirements of the

Department. We should make you a lump sum charge of say $23,000 or whatever other sum would be finally determined after all the sub-foundation conditions are known. This sum would be paid to us in equal monthly installments extending over a time sufficient to absolutely insure the completion of the work.

If you wish us to furnish plant, the precise nature of that plant would be determined and we would then furnish it either for a fixed depreciation charge or a per diem rate as you prefer.

We would furnish the expert resident superintendent and if you desire it, all the rest of the executive force. In this particular (excepting only the superintendent) we should of course accomodate ourselves to your wishes.

We would furnish skilled or unskilled labor to any extent as desired by you and I wish to emphatically state that everything to be furnished, be it labor or anything else, is furnished at its exact cost to us. In fact you assume the labor on your pay roll and pay it direct, including the superintendent and executive force. In other words our entire profit is contained in the commission which we charge and there are no concealed profits or rebates of any sort throughout the estimate. Everything furnished by us is on strict voucher subject to audit. It follows therefore that you and we would be co-operating to one end, namely the completion of the work in the quickest possible time and at the least possible cost. You recognize that the latter incentive in its effect on our business reputation is a most powerful one. It is very rare indeed that we do not beat our own time estimates. In fact we have just collected a bonus from the City of Pittsfield, Mass., which became due under a special time contract.

I would add further that if one of us comes out to discuss this matter with you, we shall wish to bring one of our construction books on some completed job so as to show you in detail the thoroughness with which our cost accounts are kept, and the results exhibited as the work progresses.

I will be pleased to hear from you at your convenience with acknowledgement of the receipt of the blue prints. I have stated already that this work interests us greatly. I will be glad if you will so put us in connection with the proposition that we will not fail to secure it through any lack of diligence on our own part.

Awaiting your further favors, we are,

Yours very truly,

AMBURSEN HYDRAULIC CONSTRUCTION CO.

W. L. Church

President.

WLC/C

Preliminary Detail Estimate.

For Proposed Dam at Leupp, Arizona.

Ambursen Hydraulic Construction Company.

Boston, Mass. Sept. 14th, 1908.

Classification	Quantities		Unit Costs	Totals
1. Clearing Site	not included			
2. New Buildings				$ 2500.
3. Erection of Plant				2000.
Hauling "				1000.
4. Coffer Dam probably nominal			say	500.
Pumping included above				
5. Cut off Trench	350	yds.	3.	1050.
6. Earth Excavation	8000	"	.30	2400.
7. Rock Excavation	200	"	2.50	500.
8. Crushed Stone or Gravel	6000	"	1.50	9000.
Boulders probably none				
9. Sand (crusher)	3000	"	1.50	4500.
10. Mixing Concrete	6000	"	.45	2700.
11. Placing Concrete	"	"	.55	3300.
12. Placing Steel	455000	lbs.	.005	2275.
13. Form Work on Dam	6000	yds.	2.50	15000.
Other Form Work	none			
14. Blacksmithing	8		400.	3200.
15. Cement Cartage	7500	bbls.	.50	3750.
Cement Handling and lost bags	"	"	.10	750.

16.	Superintendent	8	mo.	$300.	$ 2400.
	Assistant Superintendent	8	"	200.	1600.
	Engineer	8	"	200.	1600.
	Clerks (2)	8	"	200.	1600.
17.	Cartage miscellaneous				1000.
18.	Earth Embankment	none			
19.	Paving Slope	none			
20.	Dismantling Plant				1500.
21.	Roads and Approaches	not included			
22.	Back Fill	none			
1a.	Stone or Gravel	see above			
2a.	Sand	see above			
3a.	Cement - at Mill	7500	bbls.	1.10	8250.
	Freight	"	"	2.00	15000.
4a.	Rough Lumber	50	B.M.	35.00	1750.
	Dressed "	50	"	45.00	2250.
5a.	Hardware				1200.
6a.	Steel Reinforcement	455000	lbs.	.02	9100.
	Freight and cartage			.015	6825.
7a.	Gates - Head and Waste	an allowance of			3000.
8a.	Explosives	see rock excavation			
9a.	Racks and Screens	none			
10a.	Fuel, Oil, Waste	say			5000.
11a.	Flashboards	none			
12a.	Closing Dam	none			

13a.	Sheet Piling (possibly none)	an allowance of	$ 5000.
14a.	Log Piling	not included	
15a.	Use of Plant 50% on 24000		12000.
16a.	Freight on Plant	say	3000.
17a.	Insurance 2% on pay roll	say	2000.
18a.	Traveling		2000.
19a.	Power House	none	
20a.	Electric Equipment	none	
21a.	Hydraulic Equipment	none.	
22a.	Contingencies	10%	14500.
23a.	Flume and Canal	none	
	Commission 15%	say	23000.
			$178,000.

LENGTH OF SPILLWAY. As a portion of the reservoir banks consists of dykes, the length of the spillway is of vital importance. The question of maximum discharge has been roughly ascertained to be approximately 15,606 second feet. Should this maximum flood come with the reservoir full, as at the end of a wet season or the last of the spring floods it would all have to go over the spillway.

The formulas usually used to provide for a spillway in wetter countries will not work here under the conditions obtaining. This maximum flood would be discharged over the spillway of 456 feet with a depth of 4.7, using the Francis formula. As a longer spillway will lessen the heights the dykes will have to be built for safety, a longer one might be preferable. With a length of 525 feet the flood assumed, would have a depth on the crest of 4.3 feet; should we make the length 575 feet, the depth would then be 4.05 feet.

With 4 feet over the crest, the additional storage of the reservoir would not be less than 6000 acre feet which would act as a great equalizer and safety valve.

It was thought, as an additional measure of safety, to build Dyke No. 3 two feet lower than the other ones, and should the floods reach a stage where the spillway over the dam could not discharge it rapidly enough without endangering the safety of the dykes, No. 3 would be topped, and probably go out, relieving the pressure at once. The objections to this would be that such a volume of water might flow to the school and agency buildings at Leupp and damage them, although I believe that it would be cared for by the lower lands both east and south. There would also be the loss of the water stored in the reservoir down to the 526 contour. It might be advisable to put in some kind of a spillway at this point that could be topped without going out. I would suggest in this connection a concrete core wall or a row of steel sheet piling. These are details that would of necessity have to be worked out later if the project is built.

Computations of the amount of material in these dykes at various heights have been made, to enable comparisons to be made but if the dam is built to el. 537, the dykes should be to el. 542.

If lower heights of dam are used, the storage capacity will be materially decreased.

LAND AVAILABLE AND NECESSARY DITCHES. The land available comes in three separate tracts, or rather under three ditches. Under the south side ditch there is a total of about 1760 acres, some of it rather indifferent quality. This ditch will be ten miles long to cover this amount of land.

On the north side of the river we find most of the good land. Within two miles and a half of the dam is a compact body of land of about 1204 acres. This is all good land, and to cover it all the main ditch would go to about mile 4½, or a little more than 5½ miles from the dam. Below this is about 200 acres of poorer land and below still further is another body of 220 acres of excellent land. Below the 10 mile point is a body of over 5000 acres of good land, the map shows about 3400 acres of it being covered by the ditch to its 14 mile point. To cover the balance of the land in this tract will need an extension of the ditch, or the building of several miles of main laterals.

The land that lies around the School and Agency at Leupp can be irrigated from the Reservoir when it has water standing more than 6 feet above the main tunnel discharge. By taking water from a point at Dyke No. 2 at elevation 522 any of the top 15 feet of water may be drawn from this gate. There is probably 1000 acres of land that can be watered from this gate of which it is estimated 600 acres can be considered good land, though some of it will need more or less leveling. If all of the ditches are built as shown on map - Proposition No. 1, and the necessary laterals, we will have

On north side of River	7044	acres
" south " " "	1760	"
Under high outlet	600	"
Total	9404	"

Miles main canal 24.

If proposition No. 2 is built, (see below), carrying the north side ditch only to mile 4½, and leaving out the 420 acres of land lying between that point and mile 9½ we will have

On north side of River	5624	acres
" south " " "	1760	"
Under high outlet	600	"
Total	7984	"

Miles main canal 20¾ miles.

The land on the north side of the river is slightly rough in places; in others, can be irrigated with a minimum of leveling or other preparation. On the south side it is not quite so good. The quality of the soil is not quite equal to most of that on the north side, and near Tolchaco there is some alkali in the soil.

TWO PROPOSED DITCH SYSTEMS. The two propositions are as follows: Proposition No. 1 is to build the ditches as shown on the map in solid lines, carrying the full amount of water from the dam to the mouth of the canyon. At this point the ditches branch. One, the larger one, will cross the river by means of an inverted siphon, using wooden stave pipe, and extend down on the north side of the river a distance of 14 miles from the forks, covering 5024 acres of land. From about 8¾ miles to 10 miles the canal will be in the canyon of the river and would be in rock largely, and subject to overflow during extremes of high water. The south side branch would be ten miles long from the dam and would cover 1760 acres of land. In this proposition, the north side ditch would be the main one.

In Proposition No. 2, and the one that is considered the better one, the north side ditch will only be built to mile 4½, and would cover 1204 acres of land, and would only need to be a small ditch. The south side ditch then would become the large one to a point at about 7¾ miles. At this point a cross ditch would be built as shown by the broken line, crossing the river with a siphon, and connect with the north side ditch at a point 9½ miles from the junction. This would add about two miles on the south side and eliminate about 5 miles of heavy construction on the north side, and also add a second siphon. By using the second proposition 420 acres of land is left out, but this can be reached at any time by building a lateral from the north side ditch.

RECAPITULATION. In brief, this is a project to store the water of Canyon Diablo in a reservoir, near Leupp, that will have a capacity of 11,617 acre feet, and an area of water surface of 980 acres.

The reservoir is made by a dam, preferably of the gravity or buttress type, with a spillway over most of its length, and five earthen dykes closing gaps in the ridge along the north of the reservoir site.

The water to be carried in open canals. The land lies along the Little Colorado River, on both sides, the larger body being on the north or side opposite from the reservoir.

The river will be crossed by two wooden stave pipes, if proposition No. 2 is followed, and there will be 20¾ miles of main canal; the largest 10 feet on the bottom and the smallest 3 feet.

The total area of land below the reservoir and under the proposed ditches will be about 7384 acres, with an additional area of 2000 acres that can be reached by a small extension of the ditch system.

There will also be about 600 acres around Leupp that can be reached by a high line discharge and ditch taking water 6 feet above the point that the main system will discharge.

This will give a total of approximately 8000 acres that can be covered by the proposed system, and to have sufficient water for this area, with a duty of water at 3.5 feet, the reservoir should be filled 4½ times each year. With the small amount of knowledge of the discharge of the canyon there is no certainty whether there is this amount of flow <u>at the right times of the year</u>, although it is presumed that there is several times this discharge during each year.

USE. The basis for the value of any proposition is its beneficial use. In the case under consideration its beneficial use would have to be provided for by inducing the Indians to farm, bringing in Indians from other places and teaching them how to use the water.

The last published report of the Commissioner of Indian Affairs gives the population of the Navajo Extension as 450. On the basis of five to the family, this would give 90 families that live in the reservation - with say 100 able bodied men.

If ten acres was allowed each family, or rather each able bodied man, about 1000 acres would be used.

The same report puts the total number of Navajos on the entire Navajo Reservation under four superintendents as 20,450 and the number of Hopi Indians as 2,135. These Indians all inhabit the country to the north of this project, and it is very probable that quite a number of the 22,000 Indians could be induced to move south and settle on this land and cultivate it.

It is a fact, however, that the Navajo is not, and never will be, at least for generations, a farmer. He is a herdsman, and a nomad. Those of the tribe who now cultivate the soil do it as a side issue to their stock interests, and cannot be induced to raise more than they need for the actual consumption of their own immediate families. But the returned students that have been to the non reservation schools where agriculture is taught could undoubtedly be induced to settle where they could be assured of a chance to have a nice farm and assured water supply.

The Hopi Indian is more of a farmer, and the reservation on which they live is an absolute desert, and it is a serious problem how to assist them to become more progressive and self supporting. Some of them are now at Tuba, on Navajo land, where they can get water from Reservoir Canyon that is now being developed for them, and I believe that others of the tribe would be glad of the chance to settle here.

It is a fact that on the entire Reservation of both of these tribes there is not more than a few hundred acres that can be farmed at any one place with the exception of along the San Juan River in the northern part of the Reservation, and this project in the southern.

Should the Department decide that it would be a good plan to build this Reservoir, and could only place Indians on part of the area, the balance could be sold to white settlers, if it was deemed wise to open the reservation, and the money derived from the sale of the lands, used to reimburse the Treasury for the pro rata cost of the project.

COST AND
OTHER DETAILS. For detailed cost sheet and other details see the following pages where it is tabulated under various heads.

On the preliminary estimates, the dam is estimated to cost $178,000. The dykes, ditches and other work, including two miles of distributing lateral ditches is $104,786., a total of $282,786.

This would give a cost of $35.35 per acre for the land covered, and if later, it is found that the water supply justifies it, 2000 additional acres may be included at a cost not to exceed $10.00 per acre.

The estimates are only preliminary as neither ditches nor dykes have been cross sectioned, but it is believed that the yardage is more than will be found on actual location, so the question of costs on the estimates will be governed largely by the unit costs used.

CONCLUSIONS. In conclusion I would say, that owing to the magnitude of the project, the lack of definite knowledge of the water supply, both as to quantity and season of runoff, as well as the distance of the main body of land from the reservoir, I prefer to submit this report, without any recommendation.

Respectfully submitted,

W. F. Robinson

Superintendent of Irrigation.

Report of Assistant Engineer R. G. Bush.

Albuquerque N. M.

Sept. 10th, 1908.

Mr. H. F. Robinson,

Superintendent of Irrigation,

Albuquerque, N. M.

Sir:

As instructed by you, I have made a topographical survey of a reservoir site and land to be irrigated therefrom at Leupp, Arizona. Herewith is my report on same.

The proposed dam across Canon Diablo will be approximately 600 feet long. Using the bottom of the canon as a base for levels and building a dam 37 feet high, the reservoir will hold 11,617 acre feet. For a dam this height, four dykes will have to be built.

Dyke No. 1 will be at an el. of 540 feet, length, 1600 feet, maximum height 8 feet, material required 3441 cubic yards approximately.

Dyke No. 2 will be at an el. of 540 feet, length 3750 feet, maximum height 18 feet, material required 28,765 cubic yards, approximately.

Dyke No. 3 will be at an el. of 538 feet, length 380 feet, maximum height 12 feet, material required 3909 cubic yards approximately.

Dyke No. 4 will be at an el. of 540 feet, length 800 feet, maximum height 12 feet, material required 3025 cubic yards approximately.

This makes a total of 39,140 cubic yards, (approximately) of material required for dykes with dam 37 feet in height.

With a dam 35 feet high, the reservoir will hold 9742 acre feet. For a dam this height, four dykes will have to be built.

Dyke No. 1 will be at an el. of 538 feet, length 1300 feet, maximum height 6 feet, material required 1349 cubic yards approximately.

Dyke No. 2 will be at an el. of 538 feet, length 3500 feet, maximum height 16 feet, material required 19,987 cubic yards, approximately.

Dyke No. 3 will be at an el. of 536 feet, length 350 feet, maximum height 10 feet, material required 2807 cubic yards approximately.

Dyke No. 4 will be at an el. of 538 feet, length 380 . feet, maximum height 10 feet, material required 1967 cubic yards approximately.

This makes a total of 26,110 cubic yards, (approximately) of material required for dykes with dam at 35 feet in height.

If it is decided that dykes built to the height stated above do not give a sufficient factor of safety and if it is thought best to build dykes two feet higher - then,

Dyke No. 1 will be at an el. of 542 feet, length 2050 feet, maximum height 10 feet, material required 6271 cubic yards approximately.

Dyke No. 2 will be at an el. of 542 feet, length 3900 feet, maximum height 20 feet, material required 39,558 cubic yards, approximately.

Dyke No. 3 will be at an el. of 540 feet, length 390 feet, maximum height 14 feet, material required 4050 cubic yards approximately.

Dyke No. 4 will be at an el. of 542 feet, length 1150 feet, maximum height 14 feet, material required 4716 cubic yards approximately.

Dyke No. 5 will be at an el. of 542 feet, length 1650 feet, maximum height 4 feet, material required 1773 cubic yards approximately.

This makes a total of 56,368 cubic yards (approximately) of material required for dykes built to the above heights.

If at any time, water backs up in reservoir to such a height as to put the dykes in danger, then Dyke No. 3 will go out. Hence the reason for making this dyke (2) two feet lower in each of the above cases.

The acre feet were obtained on the supposition that water would be taken out of the reservoir at an elevation of 516 feet.

Mr. Maxwell, the agent at Leupp, says that a great deal of water comes down the Canon Diablo every year.

The drift line follows approximately the 518 contour.

As to material for building the dam.

Sand for concrete can be obtained within ½ mile of the dam site. Rock for concrete can be obtained within a few hundred feet of the dam site. It will be necessary to put in a rock crusher and to quarry this rock. There is no gravel in the vicinity that is fit for concrete. Water for concrete can be obtained by boring a well at the site. Sufficient water can be got within 30 or 40 feet of the surface. Water can be piped from the tank at Leupp, which is something like a mile and a half away. The capacity of the pump that fills this tank is about 2005 gallons per hour.

Canon Diablo drains a very large area, but from the information given me by the people at Leupp, very little silt is washed in.

The proposed dam site is situated between bluffs on each side of the canon. A rock ledge extends about 170 feet across part of the site. Test pots have been put down 18 feet beyond this ledge and found nothing but made dirt. So the greater portion of the dam must be figured on as having a soft foundation.

Material for the dykes can be borrowed alongside with only a berme left between toe of dyke and borrow pit.

A gate can be put in Dyke No. 2, which can be used to irrigate a school farm; but water cannot be taken from this gate when water in the reservoir is low.

As to the lands to be irrigated.

The accompanying map shows approximately 6500 to 7000 acres of land available. The ditch is to be taken out at an elevation of 516. This ditch will go down the canon to the Little Colorado River. On the south side of the river the ditch is 10 miles in length with a drop of 2½ feet per mile and covers approximately 1760 acres. Only a very small part will require any rock work. About half of the land on this side of the river is very poor.

The other half is fairly good land. To put a ditch down the north side of the river makes it necessary to siphon the river just below the mouth of the Canon Diablo. In putting the ditch across the river the loss of head caused by the siphon has been taken at three feet. There will be no rock work on this ditch as far as mile five. The area covered to this point amounts to approximately 1204 acres, all of which is good land.

From mile 5 to mile 8¾ the ditch will cover approximately 440 acres. There will be no rock work on this portion. Also 200 acres of this land is very poor.

From mile 8¾ to mile 10 2000 feet the river goes between rocky bluffs. The bank is very narrow. This portion of the ditch will be mostly rock work and will be very expensive and will be subject to overflow every year. From mile 10 2000 feet to mile 14, the end, the ditch will be easy construction and will cover approximately 3400 acres. It can be extended, provided there is sufficient water to cover between 1000 and 2000 acres more land than is shown on the map. All of this is good land and the greater part will need no clearing or smoothing off in order for it to be cultivated.

To save building ditch on north side of river from mile 4½ to mile 9½.

Starting at mile 7 3300 feet of the ditch on the south side of the river and building ditch around the hill as shown on the map for a distance of 1 mile 3800 feet. Siphon the river at this point connecting with the original ditch on the south side at mile 9½. This will give 7½ feet to allow for loss in siphon.

This way will necessitate building the ditch on the south side as far as mile 7 3300 feet larger than it would be if the second siphon was not put in.

But $3\frac{1}{4}$ miles of ditch will be saved entirely. Also the ditch on the north side from siphon No. 1 to mile 5 will then be smaller and a smaller siphon can be put in at the first crossing. So as far as the work of building ditches is concerned, things will about balance with the exception of $3\frac{1}{4}$ miles of ditch saved entirely. It would surely be cheaper to build the two siphons and lose the 440 acres of land that would be irrigated on the north side from mile 5 to mile $8\frac{3}{4}$ if that part of the ditch was built.

Respectfully,

R. G. Bush

Assistant Engineer.

Capacity of Reservoir at each contour

for Dam heights of 37 and 35 feet.

Dam 37 feet high.

Contour.	Area in square feet for each contour.	Capacity in cubic feet for each contour.
16	4,768,000	
18	7,444,000	12,212,000
20	11,154,000	18,598,000
22	16,422,000	27,576,000
24	19,834,000	36,256,000
26	23,972,000	43,806,000
28	26,804,000	50,776,000
30	31,516,000	58,320,000
32	35,137,000	66,653,000
34	37,049,000	72,186,000
36	40,828,000	77,877,000
37	42,717,000	41,772,500
	Total	506,032,500

$\frac{506,032,500}{43560}$ 11617 acre feet.

Area of Reservoir full, 980 acres.

Average depth, 1185 feet.

Dam 35 feet high.

16	4,768,000	
18	7,444,000	12,212,000
20	11,154,000	18,598,000
22	16,422,000	27,576,000
24	19,834,000	36,256,000
26	23,972,000	43,806,000
28	26,804,000	50,776,000
30	31,516,000	58,320,000
32	35,137,000	66,653,000
34	37,049,000	72,186,000
35	38,938,000	37,993,750
	Total	424,376,750

$\frac{424,376,750}{43560}$ 9742 acre feet.

Area of Reservoir full, 905 acres.

Average depth, 10.75 feet.

DYKES, - Length, Maximum Height and Contents.

	No. 1.	No. 2.
	Elevation 38	Elevation 38
Length	1300'	3500'
Maximum Height	6'	16'
Material	1349 cubic yards	19987 cubic yards
	Elevation 40	Elevation 40
Length	1600'	3750'
Maximum Height	8'	18'
Material	3441 cubic yards	28765 cubic yards
	Elevation 42	Elevation 42
Length	2050'	3900'
Maximum Height	10'	20'
Material	6271 cubic yards	39558 cubic yards

	No. 3.	No. 4.
	Elevation 36	Elevation 38
Length	350'	380'
Maximum Height	10'	10'
Material	2807 cubic yards	1967 cubic yards
	Elevation 38	Elevation 40
Length	380'	800'
Maximum Height	12'	12'
Material	3909 cubic yards	3025 cubic yards
	Elevation 40	Elevation 42
Length	390'	1150'
Maximum Height	14'	14'
Material	4050 cubic yards	4716 cubic yards

	No. 5.
	Elevation 42
Length	1650'
Maximum Height	4'
Material	1773 cubic yards

STRUCTURES.

From the map it looks as if the cross drainage would have to be provided for in eight places, this seems rather a small number. However have estimated 8 @ $250. each, or $2000. on the ditch line; and for the two siphons 150 yards concrete @ $20. per yard or $3000. Total $5000.

Lateral Headgates or Turnouts.

Estimated Number 25.

Unit Cost	$40.
Total Amount	$1000.

For Bridges, Flumes, etc., have added $1000., making a total for structures $7000.

For slope paving it is assumed that the paving will be one foot thick, and the total slopes of all of the dykes is 11,886 square yards. The total quantity of rock needed will be 3,962 cubic yards.

Table of Ditch Sizes and Capacities

Side Slopes
Sidehill upper 1:1
" lower 1½:1
all earth 1½:1
Rock 1:1

Fall 2.64 per M.
S = .0005
√S = .02236

Approx. Capacity in Sec. Ft.	Bottom Width	Width Banks	Height Banks	Average Excavation per Station	Depth Water	a	r	v	Q
100	10	50	45	200	32	448	220	22	99
115	"	"	"	200	35	503	236	23	115
130	"	"	"	225	38	560	253	24	133
90	"	"	"	140	30	435	209	209	91
85	"	"	"		29	416	204	208	85
70	"	"	"	"	27	379	194	190	718
60	8	40	40	80	28	341	188	183	62
50	"	"			26	309	178	173	53
45	"	"	"		24	278	168	165	46
45 Rock	"	"	"	100	25	2625	200	18	47
25	6	40	30	70	20	180	137	151	27
25	"		"		19	160	129	147	245
20	"			"	18	158	112	143	226
15	5		28	56	16	118	11	131	155
10	3½	30	25	40	15	88	97	121	107
[illegible] 10	30	30	"	30	15	79	94	Varies with S	

[illegible]

Proposition No 1

Summary - Using One Siphon

Sta to Sta	Acres Under Ditch	Computed Capacity Sec Ft	Computed Capacity + Seepage Sec Ft	Yds Earth	Yds Rock	Cost Excavation	Remarks
0 to 59		105	130		15500	15500	In Canon
1st Siphon				1600		1600 2100	Net excavation Siphon
62 to 160	600	80	90				
160 275	650	70	80	58000		14500	
275 475	450	60	70				
475 580	1400	45	50	2400	7500	8100	
580 740	1900	25	30	11200		2800	
South Side							
59 to 210	500	25	40	12000		3000	
210 370	350	15	25	11200		2800	
370 403	450	10	15	1600		400	
403 528	400	10	10	5000		1250	
Distributaries 2 Miles				3200		800	
Total	6700			106200	23000	52850	

Proposition No 2
Summary - Using Two Siphons

Sta to Sta	Acres Under Ditch	Computed Capacity Sec Ft	Computed Capacity + Seepage Sec Ft	Yds Earth	Yds Rock	Cost Excavation	Remarks
0 to 59		105	130		15500	15500	In Cañon
Siphon No 1				1200		1200 1400	Net Exc Siphon
62 to 160	600	25	30	15000		3750	
160 " 275	650	15	20				
South Side							
59 to 210	500	80	100	30000		7500	
210 to 370	350	70	90	27000		6750	
370 " 403	450		80				
403 " 528			10	5000		1250	
403 " 503			60	8000		2000	
Siphon No 2				3000		3000 3150	Net Exc Siphon
North Side							
510 to 580	1400	40	50	5600		1400	
580 " 750	1900	25	30	12000		3000	
Distributaries 2 Mi.				3200		800	
Total	6250			110000	15500	50700	

[illegible]

PROPOSITION No. 2.

Estimate in detail with unit costs.

Dykes. to el. 542				
Earth -	56,368 cu. yds.	@ 25 cents	cu. yd.	$14,092.
Slope paving -		@ 50 "	sq. yd.	5,943.
Outlet at high elevation -		estimated		300.
Ditches.				
Excavation Class I				
	105,800 cu. yds.	@ 25 cents	cu. yd.	26,450.
	3200 cu. yds. wet	@ $1.	cu. yd.	3,200.
Excavation Class III				
	15,500 cu. yds.	@ $1.	cu. yd.	15,500.
Siphons.				
No. 1.				
Concrete, reinforced -				
	75 cu. yds.	@ $20.	cu. yd.	1,500.
Stave Pipe -	350' (24")	@ $4.	ft.	1,400.
Excavation, wet -				
	1200 cu. yds.	@ $1.	cu. yd.	1,200.
No. 2.				
Concrete, reinforced -				
	75 cu. yds.	@ $20.	cu. yd.	1,500.
Stave Pipe -	700' (30")	@ $4.50	ft.	3,150.
Excavation, wet -				
	3000 cu. yds.	@ $1.	cu. yd.	3,000.
Structures.				
Cross drainage -	8	@ $250.	each	2,000.
Lateral headgates -	25	@ $40.	"	1,000.
Bridges and flumes -		estimated		1,000.
Clearing.				100.
Freight on tools.				500.
Buildings.				1,000.
				82,835.
Superintendence and Engineering, exclusive of dam 15%				12,425.
				95,260.
Contingencies. 10%				9,526.
				104,786.
Dam. see detail Ambursen letter				178,000.
	Estimated total cost			282,786.

Estimated cost per acre $35.35