THESIS

SOME OBSERVATIONS

ON THE

FLOW OF WATER

FOR DEGREE OF C. E.

GEORGE HENRY ELLIS

1912

THESIS.

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Some Observations on the Flow of Water.

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For Degree of Civil Engineer

By Geo. Henry Ellis.

1912.

THESIS

Some Observations on the Flow of Water.

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Some Observations on the Flow of Water

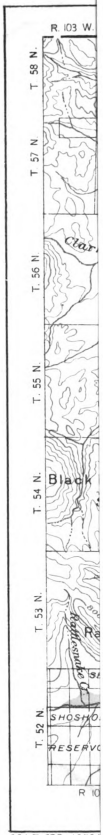
Introduction.

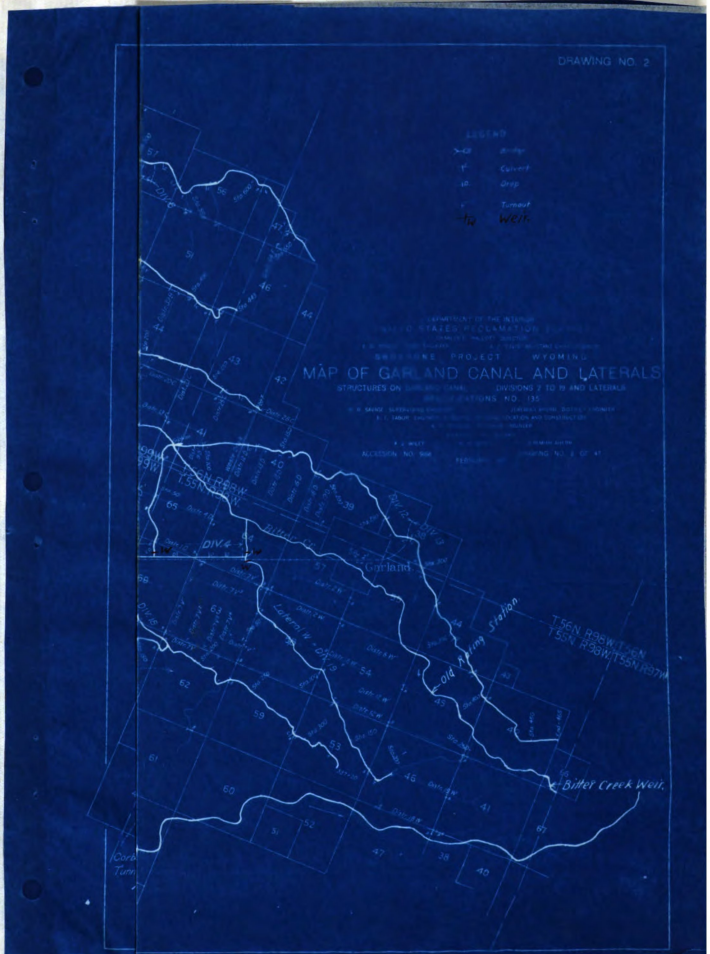
It was the writers privilage during the irrigating season of 1911, to be at the head of the Hydrographic Department of the Shoshone Project, Wyoming. This department was not organized on the Shoshone Project until the season of 1911. At that time two paved sections had been installed in the main canal, but beyond this there was nothing bequeathed to this new department from any previous organization. Rating curves were determined and weirs were installed after the beginning of the season. The following maps, the one showing the general location of the Project, and the other the location of the canals as at present completed, are inserted here for reference in the pages that follow.

The second feet is the unit used to denote rate of flow. It, as its name implies means one cubic foot per second. Quantities of water are expressed in terms of Acre feet. One acre foot is 43560 cubic feet, or the amount necessary to cover one acre, one foot deep. One second foot flowing for 24 hours, equals 1.98 acre feet. For rough calculations, one second feet is taken as two acre Feet per day.

Description and Accuracy of Current Meter Work, and Miscellaneous Data Deducted Therefrom.

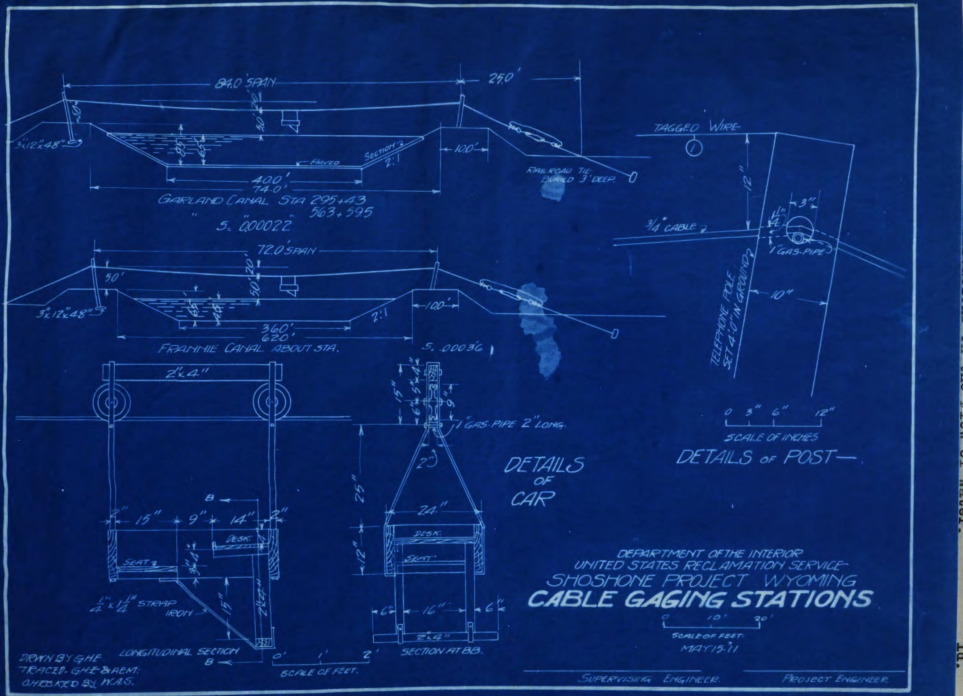
At the end of the season, the computations of all ratings were checked and plotted and final rating curves established. These curves were then assumed to be correct,


R. 103 W.
T. 58 N.
T. 57 N.
T. 56 N.
T. 55 N.
T. 54 N.
T. 53 N.
T. 52 N.
Clar
Black
SHOSHO
RESERVO
R 10
MAP NO. 10504


DRAWING NO. 2
LEGEND
Bridge
Culvert
Drop
Turnout
Well
MAP OF GARLAND CANAL AND LATERALS
SHOSHONE PROJECT WYOMING
STRUCTURES ON SHOSHONE CANAL DIVISIONS 7 TO 11 AND LATERALS
T.56N. R.98W.
T.55N. R.98W.
DIV.4
Garland
Cold Spring Station
T.56N. R.97W.
T.55N. R.97W.
Billet Creek Well
Canal

Drawing No. A.

Drawing No. B.



Some observations on the flow of water. 14.

1270

Photo No. 1.

Photo No. 2.

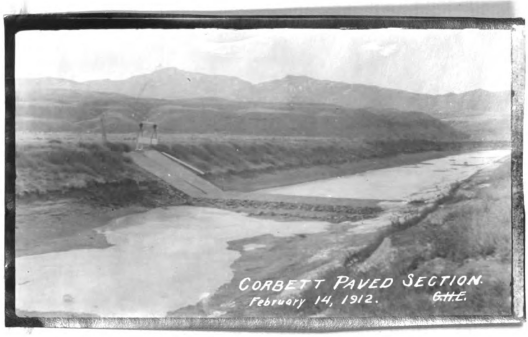


Photo No. 3.

Photo No. 4.

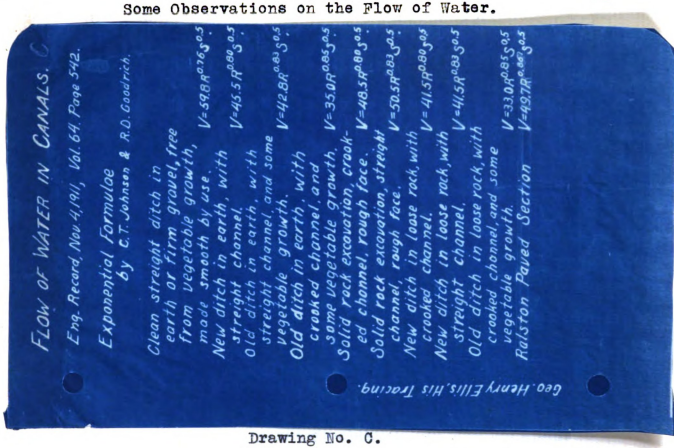
and the error of each individual rating was computed in percentage of flow and tabulated on Drawing No. A. This gives a general idea of the consistency of the work, and as it was done by two different men and current meters, of its accuracy, also.

The Corbett and Ralston paved sections are located on the Garland Canal (The Main Canal) at stations 295 and 564 respectively. They consist merely of a strip of paving of cement blocks, 6" thick, 15' wide, and conforming to the section of the canal, which is 40' bottom and 2 : 1 side slopes. This paving is too short to be of much value as a rating flume, but it affords a constant section, which is desirable. Three ratings by wading were taken at each of these stations, after which a cable and car were installed, as shown on Drawing No. 1270, and Photos Nos. 1 and 2. These cars have worked very satisfactorily. Wading measurements are undesirable, as it is difficult to hold the meter where it is not affected by the eddy around the legs of the observer.

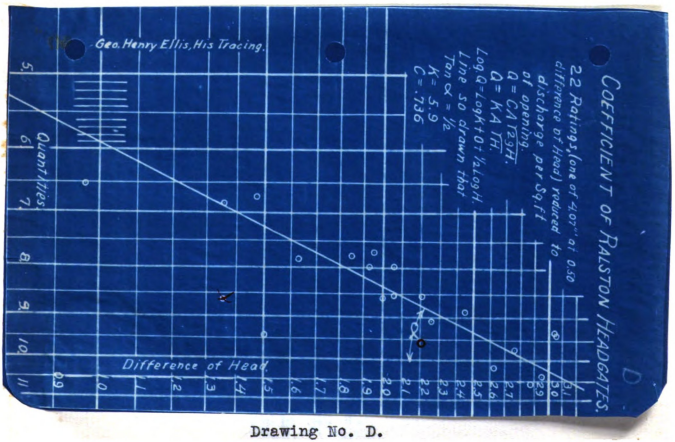
The contractors had borrowed out of the bottom at the side of the Corbett paved section, and the paving was built up to grade, so that it has an action somewhere between that of a rating flume and a submerged weir. This difference is shown in photos Nos. 3 and 4, and in the rating curves for the two stations, Drawing No. W-3097. It is noticeable how closely the Ralston curves resembles Kutter's curve for that section.

From the ratings of the Ralston section an exponential formula has been deduced, for which see drawing No. B.

Some Observations on the Flow of Water.



Drawing No. C.



Drawing No. D.

Photo No. 5.

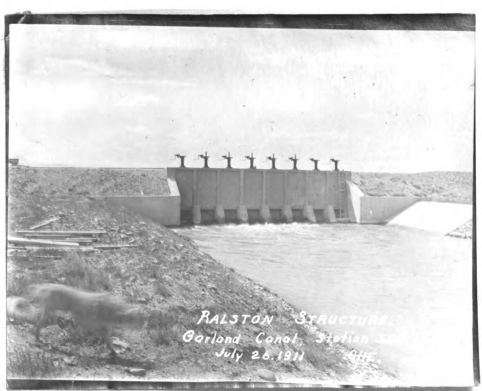


Photo No. 6.

Photo No. 7.

Photo No. 8.

Drawing No. C. is inserted for comparison with other data of similar nature.

The headgates which control a small equalizing reservoir at Ralston are situated at Sta. 555, as shown on the map, just above the paved section; and the attempt was made to find a coefficient for their discharge. See drawing No. D. Quantities were taken off the rating curve, rather than from individual ratings, so that the wide scattering of the points is due to errors in reading the gages and gate openings, rather than in the quantities. The coefficient for these gates, (see photos Nos 5 and 6) will vary with the gate opening, as the ratio of full contraction to suppressed contraction. The attempt will be made to get some better data on these gates during the coming season.

A portion fo the Garland Canal runs across a country so steep that it is provided with concrete drops spaced about every 10 to 20 stations. These drops, (photos Nos. 7 and 8) are of three different lengths of crest, but are all of the same general design. It was desired to find the loss of water between these, and rating stations were therefore established at each of them. Three of these were provided with foot-bridges supported on bents which caused some eddying. The wading measurements were taken under conditions which were sometimes favorable, and sometimes otherwise. The ratings were all reduced to one formula, $Q=4(L-0.3H)H^{1.50}$ and the errors of individual ratings, shown on drawing No. A.

INCREASE OF WEIR DISCHARGE in percentage of Normal Flow, due to VELOCITY OF APPROACH, by Francis' Formulae, $Q = 3.33 L(H^{\frac{3}{2}} - h^{\frac{3}{2}})$, $H = [(Dth)^{\frac{2}{3}} + h^{\frac{2}{3}}]^{\frac{3}{2}}$, $h = \frac{2}{3}$ See W.S.& I. Paper No. 200, P. 25.

Observed Head D	VELOCITY OF APPROACH 0.5'	1.0'	1.5'	2.0'	2.5'	3.0'
0.1	5.32	18.90	36.29	57.17	80.33	106.85
.2	2.75	10.14	20.04	32.41	47.15	63.37
.3	1.81	6.93	14.12	23.12	33.83	45.88
.4	1.44	5.31	10.89	18.00	26.59	36.22
.5	1.15	4.31	8.89	14.78	21.91	30.05
.6	.93	3.64	7.52	12.56	18.71	25.74
.7	.80	3.11	6.50	10.93	16.31	22.54
.8	.71	2.74	5.71	9.68	14.49	20.07
.9	.65	2.43	5.10	8.69	13.04	18.10
1.0	.59	2.16	4.55	7.89	11.87	16.50
1.1	.55	1.96	4.11	7.23	10.89	15.16
1.2	.51	1.80	3.77	6.68	10.06	14.03
1.3	.47	1.66	3.49	6.19	9.35	13.06
1.4	.43	1.54	3.27	5.77	8.73	12.21
1.5	.39	1.44	3.09	5.42	8.20	11.48
1.6	.36	1.35	2.94	5.10	7.73	10.83
1.7	.34	1.29	2.80	4.83	7.31	10.25
1.8	.33	1.23	2.67	4.58	6.94	9.73
1.9	.32	1.17	2.54	4.34	6.60	9.26
2.0	.31	1.12	2.37	4.14	6.29	8.84

Computed and checked by [illegible]
Probably Correct to the nearest 01

Geo. Henry Ellis, His Tracing.

Drawing No. H.

Photo No. 9.

Photo No. 10.

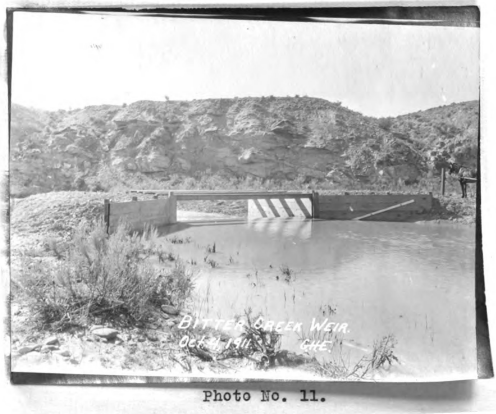
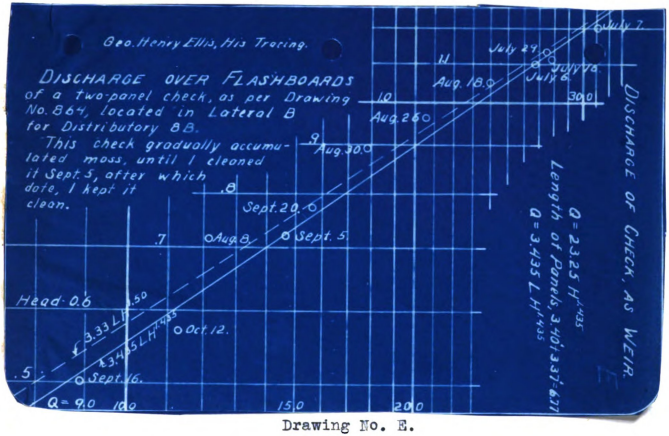


Photo No. 11.



Drawing No. E.

Photo No. 12.

are based on it. This method introduces errors caused by the individuality of each station, but it was thought best to have one formula for all drops.

It has been thought that by correcting each rating for the velocity of approach, and then finding a new formula, allowing for the velocity of approach, the error of individual ratings would be less than those shown on Drawing No. A; and the table in Drawing No. H. was gotten up for that purpose. This method would however require a knowledge of the velocity of approach for each tenth of head on each drop, and would be to cumbersome for practical use.

The Bitter Creek (Old) station was merely a footplank across the creek, from which ratings were taken. See Photo No. 9. The bottom is rocky and subject to change. Two different curves were used for this station, one before, and the other after a certain heavy rain in July. The average error shown on drawing No. A is based on the two curves. The bitter Creek station has since been moved farther down the creek, and a weir installed. See Photos Nos. 10 and 11. The crest of this weir is hinged so that it can be let down, and the silt sluiced out.

The check in Lateral "B", for the "8B" distributary, was the division point for two of the ditch-riders. A rating station was established at this point, at the request of the Operation and Maintenance Department. These ratings were plotted on drawing No. I, and the formula deduced as shown there and in photo No. 12.

Photo No. 13.

Photo No. 14.

Photo No. 13 shows a larger check of the same general design.

The Alkali Creek Flume is a small temporary structure, carrying the main canal down a sharp incline and across the creek. See photo No. 14. The quantities actually carried are based on the rating curves of two current meter stations. Depth of water in the flume was measured during the last days of the season at four different points. One of these points proved to be too close to the entrance, where the grade for a short distance is very much steeper, so that the average of the other three was taken as the depth. The ratings obtained in this manner were plotted on drawing No. W-3202. for easy comparison with the computed discharge for different values of N.

Description and Accuracy of Weir Measurements.

Photo No. 15 shows the general design of the 10, 15, and 20 ft. weirs. Francis' formula ($Q=3.33LH^{1.50}$) was used in connection with all weirs. There was some question as to whether Cippoletti's formula should not be used with Cippoletti weirs. The outward slope of the ends of the Cippoletti weir is theoretically just enough to balance the end contractions determined by Francis. Cippoletti derived his formula from a discussion of Francis' experiments, selecting a coefficient 1.11% greater; $Q=3.367LH^{1.50}$. Suppose, for a minute, that Francis' value of the end contractions were incorrect, and that the flared ends did make a difference of 1.11% in the discharge of Cippoletti weir, say 10 ft. long. It is

Subject COMPARISON OF ERRORS IN CONNECTION WITH WEIRS.

Date Computer G.H.E.

For other references see The U.S.G.S. Water Supply + Irrigation Paper No. 200 Checked by P.H.9

Head.	Discharge per Foot of Crest by Francis's Formula. See W.S.+I. Paper No. 200. Page. 68. These Values Assumed Correct for Purposes of This Sheet.	% Coefficient of Error by Fuzzing Formula, W.S.+I. Paper No. 200 p.57.	Percentage of Error of Reading Gage 0.01 Ft. High.	Percentage of Error of Crest Not Level by 0.1 Ft. W.S.+I. Paper No. 200, p. 57.	Cippoletti's Formula gives results uniformly 1.11 per cent greater than Francis.
0.1	.10 53	+ 21.2	15.3	+ 2.19	
0.2	.29 78	+ 9.3	7.6	- 0.10	
0.3	.54 72	+ 5.4	5.0	- 0.57	
0.4	.84 24	+ 3.5	3.8	- 0.65	
0.5	1.17 73	+ 2.3	3.0	- 0.77	
0.6	1.54 76	+ 1.5	2.5	- 0.88	
0.7	1.95 03	+ 0.9	2.1	- 0.85	
0.8	2.38 28	+ 0.5	1.9	- 0.84	
0.9	2.84 32	+ 0.2	1.7	- 0.83	
1.0	3.33 00	- 0.1	1.5	- 0.90	
1.1	3.84 18	- 0.3	1.4	- 0.87	
1.2	4.37 74	- 0.4	1.3	- 0.88	
1.3	4.93 58	- 0.6	1.2	- 0.89	
1.4	5.51 62	- 0.8	1.1	- 0.89	
1.5	6.11 76	- 0.9	1.0	- 0.87	
1.6	6.73 94	- 1.0	0.9	- 0.89	
1.7	7.38 10	- 1.1	0.9	- 0.89	
1.8	8.04 18	- 1.1	0.8	- 0.89	
1.9	8.72 12	- 1.2	0.8	- 0.89	
2.0	9.41 87	- 1.3	0.8	- 0.89	

36 tests were made by running the same amount of water over a weir which had silted up, and over a similar weir which had not silted up. This weir had probably silted up as much as it ever will, as part of the silt washed out during the tests.

On 3 tests, the silted up weir read .015 ft. high on 7, it read .010 ft. higher on 4, it read .010 ft. lower on 7, it read .005 ft. higher on 5, it read .005 ft. lower on 10, they read the same.

Traced by J.S.S.
Checked by P.H.9

Y-G-2316.

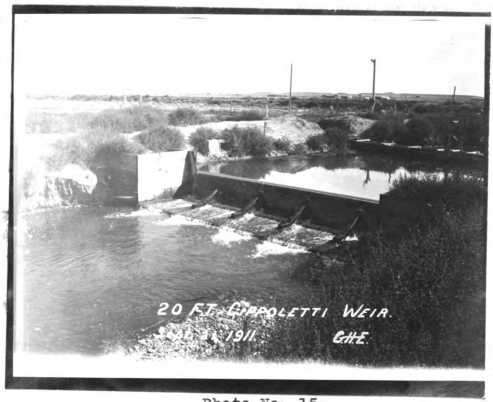


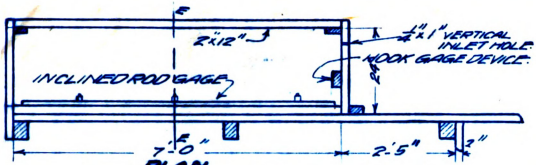
Photo No. 15.

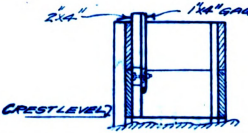
Photo No. 16.

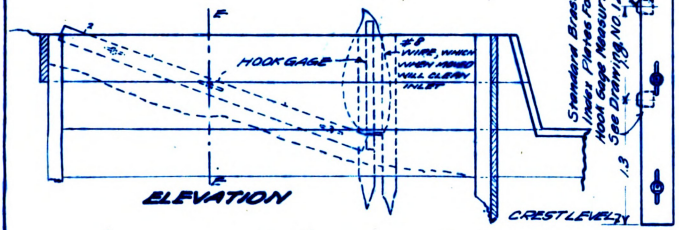
evident that in a 100 ft. weir for the same head, the increase due to those flared ends would not be such a large percentage of the whole, and yet Cippoletti's formula would still give a discharge 1.11% greater than Francis'. It is therefore proper to select either one or the other of the formulae and use it throughout.

In the accompanying table, drawing No. 6-2316, the attempt has been made to compare some of the different ways in which weir measurements may be in error. It is noticeable that the error obtained in any of the assumed cases compares favorably with the difference between the formulae proposed by the original experimenters. Drawing No. H has been made up later, to show the effect of different velocities of approach.

Hook gages were used at all weirs, with stilling boxes placed ten to twelve ft. up-stream from the crest. The openings to these boxes silted up so that they did not act properly, and the boxes themselves settled in the mud so as to be inaccurate, so that finally, inclined rods were nailed directly to the face of the weir, as shown in photo No. 16, for a check. The scales on these rods are exagerated three times and were marked as follows. First the rod was made up of 1" X 4" stuff, given two coats of white paint. Then each hundredth (actually every three hundredth) was marked by a saw cut full of black paint. The tenths are distinguished by brass racks, half feet by two brass tacks, and even feet by four brass tacks. After allowing for inaccuracies due to setting,

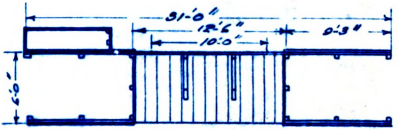






DETAILS OF GAGE RODS ATTACHMENTS

SCALE OF INCHES



PLAN OF 10' CIPOLETTI WEIR

SCALE OF FEET

SEE DRAWING # W.L. 126.7.

DEPARTMENT OF THE INTERIOR
UNITED STATES RECLAMATION SERVICE
SHOSHONE PROJECT WYOMING
STILLING BOX FOR WEIRS

SCALE OF FEET

JANUARY 22, 1912

Drawn by G.H.R.
Traced " A.R.M.
Checked " R.W.H.

SUPERVISING ENGINEER

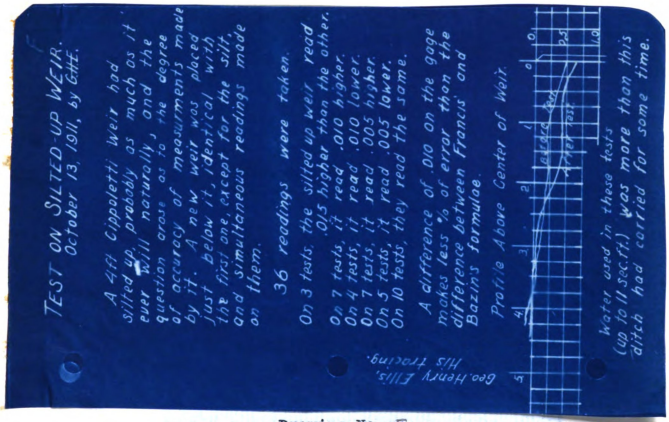
PROJECT ENGINEER

VE 8060

S-3676

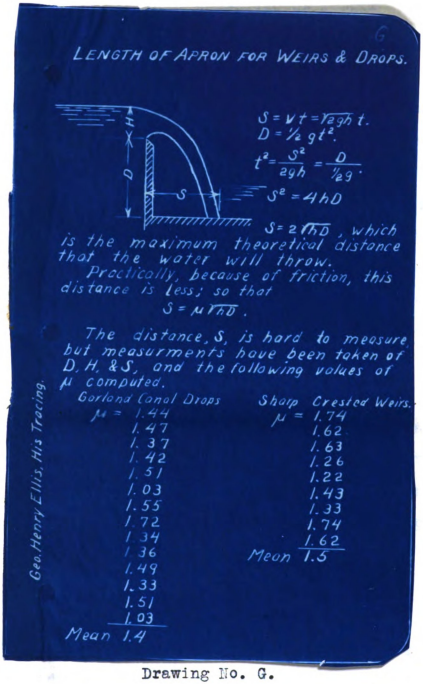
Some Observations on the Flow of Water.

68.



Drawing No. F.

Photo No. 17.


G
LENGTH OF APRON FOR WEIRS & DROPS.
H
X
D
S
$S = Vt = \sqrt{2gh}\, t.$
$D = \frac{1}{2} g t^2.$
$t^2 = \frac{S^2}{2gh} = \frac{D}{\frac{1}{2}g}.$
$S^2 = 4hD$
$S = 2\sqrt{hD}$, which is the maximum theoretical distance that the water will throw.
Practically, because of friction, this distance is less; so that
$S = \mu\sqrt{hD}$.
The distance, S, is hard to measure but measurments have been taken of D, H, & S, and the following values of μ computed.
Gorlond Canal Drops
μ = 1.44
1.47
1.37
1.42
1.51
1.03
1.55
1.72
1.34
1.36
1.49
1.33
1.51
1.03
Mean 1.4
Sharp Crested Weirs.
μ = 1.74
1.62
1.63
1.26
1.22
1.43
1.33
1.74
1.62
Meon 1.5
Geo. Henry Ellis, His Tracing.

Drawing No. G.

settlement, etc., these two forms of gages checked each other to the nearest hundredth of a foot. It is the opinion of the writer, therefore, that for practical work, outside of a laboratory, the inclined rod is preferable to the hook gage, because it is handier, and easier to read. One of those in the photo is graduated to read directly in second feet. The rod should however be protected by a stilling box with the smallest possible inlet, and should be adjustable. The stilling box should be rigidly attached to the weir structure, and arranged to be easily cleaned. The writer has put his ideas of a stilling box into drawing No. S-3676. This design has been approved and will be installed on the larger weirs this season.

Some of the smaller weirs silted up and tests were run to show the effect of this silt on the discharge. These tests are described in drawing No. F and Photo No. 17. The writer is not yet ready, however to ignore the effect of silt on his weirs, and the later designs provide an opening just under the crest for sluicing.

The data in drawing No. G was gotten on the side. It is self explanitory, except that it might be well to add that the nappe of the Garland Canal drops is suppressed, that is, there is no provision for air to get under it, and the vacuum thus formed tends to pull it down.

The Ten Day Reports.

It was the duty of the Hydrographic Department to gather data for and make up the ten day reports, and to cooperate in so far as possible with the Operation and

TOTAL FOR SEASON 1911.

DEPARTMENT OF THE INTERIOR
U.S. RECLAMATION SERVICE SHOSHONE PROJECT WYOMING
SEASON REPORT ON WATER April 21 to October 31 1911.
ALL QUANTITIES IN ACRE F.T.

A SHOSHONE DAM BEGINNING OF PERIOD GAGE AT		STORAGE	
END " "		"	
INFLOW MINUS LOSS DURING PERIOD			88415
OUTFLOW "			
Over Corbett Dam			826035
B CORBETT TUNNEL INTAKE TO GARLAND CANAL INTAKE			
Gates opened April 21, INFLOW DURING PERIOD	(100 %)		55380
Closed October 24, noon OUTFLOW " "	54862 = 99.2 %		
WASTED AT SLUICE GATES	58 = 0 %		
LOSS	460 = 0.8 %		55380
Report of .98" August 6 at Ralston raised Reservoir a foot	20		
C GARLAND CANAL INTAKE TO RALSTON HEADGATE			
Gates opened April 25 INFLOW DURING PERIOD	54862 = 99.2 %		
Closed October 24 mid-night IN RALSTON RESERVOIR AT BEGINNING	0		54882
OUTFLOW AT RALSTON HEADGATE	49922 = 90.2 %		
DIVERTED IN TO LATERALS	16 = 0 %		
WASTED AT EAGLENEST AND RALSTON	463 = 0.8 %		
Oct 25 IN RALSTON RESERVOIR, END OF PERIOD	704 = 1.3 %		
LOSS DURING PERIOD	3777 = 6.9 %		54882
D GARLAND CANAL BELOW RALSTON HEADGATE			
INFLOW DURING PERIOD			49922
DIVERTED TO LATERALS	48813 = 88.2 %		
WASTED AT LOWER ENDS	1890 = 3.4 %		
LOSS DURING PERIOD	781 = 1.4 %		49922
E LATERALS AND DISTRIBUTARIES			
INFLOW DURING PERIOD			48829
DELIVERED TO FARMERS	35787 = 64.6 %		
WASTED AT LOWER ENDS	1184 = 2.1 %		
LOSS DURING PERIOD	11858 = 21.5 %		48829
F FARMERS' INDIVIDUAL DITCHES			
INFLOW DURING PERIOD			35787
RETAINED ON LAND	28240 = 51.0 %		
WASTED	7547 = 13.6 %		35787
G DRAINAGE SYSTEM RUNOFF Gravel Pit installed Aug 17			2 0 1/2
NET TOTAL B, C, D, E & F.			
INFLOW (B) CORBETT TUNNEL Plus rain at Ralston (100 %)			55400
BENEFICIALLY USED (F)	28240 = 51.0 %		
WASTED BY U.S. (B, C, D & E)			
SLUICING GATES	521 = 00.9 %		
LOWER ENDS	3074 = 5.5		
WASTED BY FARMERS (F)	7547 = 13.6		
LOSSES (B, C, D & E)	15314 = 27.7		
INCREASE IN STORAGE (RALSTON)	704 = 1.3		55400

COMPUTED BY GAHE CHECKED BY PMS

PROJECT ENG. WEST

V G-129420

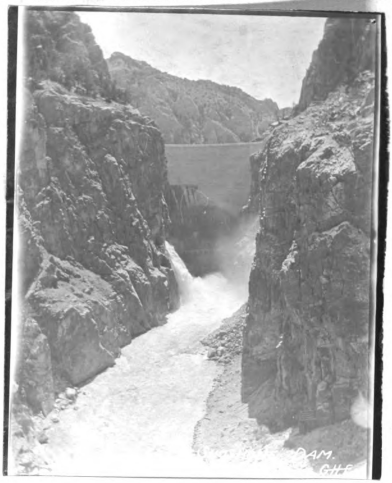
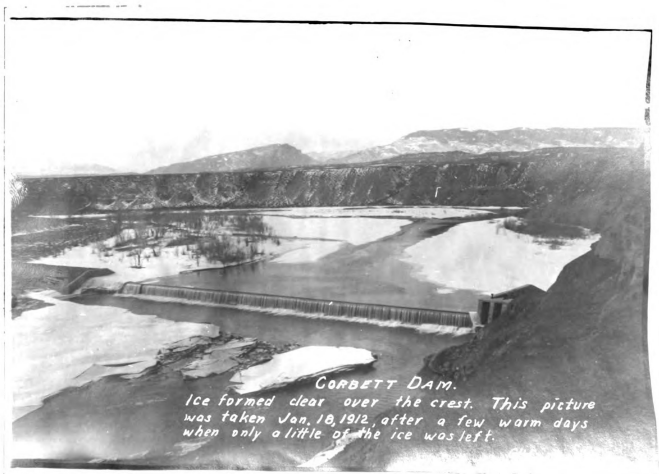
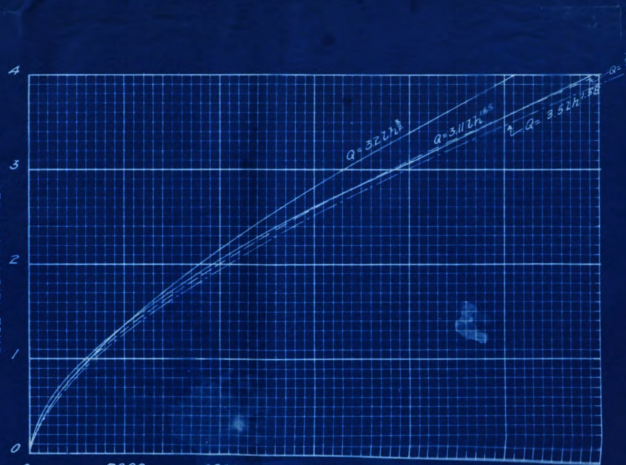


Photo No. 18.

Photo No. 19.





FORMULA $Q = 3.2\, L h^{\frac{3}{2}}$ SUGGESTED BY MR. M.O. LEIGHTON
FORMULA $Q = 3.11\, L h^{1.65}$ SUGGESTED BY MR. W.A. LAMB
FORMULA $Q = 3.3\, L h^{1.6}$ SUGGESTED BY MR. E.E. SANDS
FORMULA $Q = 3.5\, L h^{1.5}$ FORMULA ADOPTED BY U.S.G.S. SEE LETTER DATED JANUARY 2ND 1912 FROM MR. W.A. LAMB DISTRICT HYDROGRAPHER

DEPARTMENT OF THE INTERIOR
UNITED STATES RECLAMATION SERVICE
SHOSHONE PROJECT WYOMING

DISCHARGE OVER CORBETT DAM BY VARIOUS FORMULAE

MARCH 14, 1911

Drawn By F.W.T.
Traced By F.N.T.
Checked By O.H.C.

Chas. D. Williams
SUPERVISING ENGINEER
PROJECT ENGINEER

Cd-286

Some Observations on the Flow of Water. 70.

Maintenance Department in the measurement of water. Drawing No. 1294.20 shows the totals for the entire season, made up on a ten-day report blank.

Referring to this sheet, the waters of the Shoshone river are stored in the reservoir above Cody, by the highest dam in the world, photo No. 18. They are allowed to run down the river and are picked up again by the diversion dam at Corbett, Photo No. 19. Shoshone is the Indian word for "Stinking Water", so called because of the sulphur springs near Buffalo Bill's town of Cody. Water is measured over the Corbett Dam by using the crest as a weir, by the formula, $Q=3.5LH^{1.58}$. This crest has never been rated, but the different proposed formulae agree pretty well, see drawing No. Cd-286, and the above has been adopted by the U. S. Geological Survey.

In the first section of canal, noted as B on the drawing, the water is measured out at the Corbett paved section. The entire flow was wasted for a period of three hours during the summer, making the 58 acre feet. The loss is estimated at 1½ second feet by watching it where it comes out as springs on the river bank below. This is easy, as it all comes out above the rim rock. The first 182 stations of this section are in tunnel.

In the next section the water is measured in at the Corbett paved section, and out at the Ralston paved section, allowing each time for the storage in the small equalizing reservoir at Ralston. Land up there was opened to entry last season, and one man took 16 acre feet of water duringthe last few days of the season's run.

There is a Wasteway at Eaglenest Creek and a sluice gate in the Ralston Reservoir. After everything measurable has been accounted for there are still left 3777 acre feet needed to balance the amount measured in. This loss averages 10.25 second feet for the 186 days of the season. Assuming an average flow of a little over two feet deep, the wetted perimeter of this section (same as both paved sections) is 5000 sq. ft. per station. If the loss per station of reservoir is the same as the loss per station of canal, and if the area through which loss by seepage occurs from the reservoir is the same as the wetted perimeter of the canal, then in the 269 stations between the two paved sections, there are 1345000 sq. ft. of wetted perimeter. This gives an average loss of 1 sec. ft. per 131000 sq. ft. or 7.63 sec. ft. per 1000000 sq. ft. of wetted perimeter.

The Garland Canal below Ralston Headgate gets into the irrigated country, on some of which, seepage conditions are apparent. In this section are located the drops, on which observations were made, as noted elsewhere in this paper. Some of them showed a loss of a few second feet, and some a gain, but the net result as shown by this final report, is a gain of 781 acre feet, or an average of 2.12 second feet for the 186 days of the irrigating season. Water was measured into this section at the Ralston paved section, and out over thirteen Cippoletti weirs, including the one in the wasteway at the lower end. Gages on these weirs were read as soon after noon as possible, when the canal was settled after changing the

gates in the morning, and compared with the noon reading at Ralston, to get the loss. This loss was then compared with the average of three readings at Ralston, to get the amount diverted to laterals.

In the Laterals and Distributaries, the inflow is the amount computed as above, plus the 16 acre feet diverted above Ralston. The amounts wasted and delivered are measured and estimated by the ditchriders, and the loss is the required balance.

The inflow to the farmer's individual ditches is the above estimate by the ditchriders. Nearly all of the territory under cultivation drains into Bitter Creek. The amount of surface waste water getting directly to the river is assumed to be off_set by the amount of seepage in Bitter Creek. This seepage was measured, after the close of the season, and was about seven second feet. The main canal and three of the laterals waste into Bitter Creek. Deducting these amounts from the total flow of the creek gives the farmer's waste. The amount retained on the land is the required balance.

The Drainage System is still being installed.

This final report has been computed in percentage of the total amount diverted. 64.6% was delivered to the farmers, of which 79%, or 51% of the tatal amount diverted, was retained on the land.

Evaporation.

Evaporation records were kept from the latter part of July to the end of the season. The Weather Bureau is

Photo No. 20.

Photo No. 21.

Photo No. 22.

attempting to find a formula so that knowing the temperature, humidity, wind velocity, and a few other things, the evaporation at that particular instant can be computed. No attempt was made on this project to go into any such refinement, the object being merely to obtain the evaporation for this locality.

Four pans were used, of the type regularly supplied by the Weather Bureau, three and four feet in diameter. Index points were soldered in the center of these and protected by stilling boxes, as shown in Photo No. 2o, and the evaporation was measured by weighing the amount of water necessary to bring the surface up to this point each time, and allowing for precipitation. Of the four pans, one is on a tower, eleven ft. high, shown in photo No. 21, and another on the edge of a field of alfalfa, both at Powell. A third is out on the unbroken prarie at Ralston, protected by a chicken wire fence, and the fourth, shown in photo No. 22, floats in the reservoir, protected from wave action by a raft.

Average Evaporation on Shoshone Project, Wyoming, in inches per day.

Month	Tower Pan	Alfalfa Pan	Prarie Pan	Reservoir Pan
July Avg. of Observations.	.405	.254	.432	.300
Aug., 31 days.	.391	.266	.342	.246
Sept.,30 days.	.287	.188	.246	.183
Oct., 31 days.	.146	.102		
Oct., 23 days.			.145	.103

The Fluctuation of the Ground Water Level.

The fluctuation of the ground water level is fast becoming a necessary study, as the reclamation of seepage lands, and the prevention of further damage by seepage is one of the most serious problems in an irrigated country, today. It is as impossible to predict in a country which is to be irrigated, just where the seepage will break out, as it is to tell where a fire is liable to start in a town of wooden buildings. Prior to any irrigation, water was obtained for domestic purposes at Camp Colter (now the town of Powell) at 35 ft. At camp F. 3½ miles up the canal (where the Frammie takes off) water was found at 70 ft., but not in sufficient quantities for camp use until a depth of about 110 ft. had been reached. Today, after four years of irrigation, water stands in the cellars in the town of Powell. The country around camp F. has not been irrigated so much, but water stands at about 30ft.

The ground water travels down the general slope of the country, until it comes out in some drain, either natural or artificial. Any strata of impervious material in the soil acts as a check in a canal, and forces the water up, until in the more aggravated cases it comes out on top or so close to it that the capillary action of the soil brings it out. All the soil in this western country contains a greater or less percentage of alkali salts which have not yet been leached out as they have in the eastern states, where it rains. These salts disolve in the ground water, and are carried with it wherever it goes. When this water is

allowed to come to the surface and evaporate, the alkali is left, just like the crystals of salt on the surface of butter which has been left some time. This process goes on until the alkali is concentrated so badly in some places that all plant life there is killed. The writer has seen a tenderfoot mistake a bad patch of alkali for snow in October.

The remedy is to have less ground water. This can be done by inducing the farmers to be more careful in their use of water, and by drains to carry the ground water off faster. The attempt has been made on this project to limit the farmers to three acre feet per acre per season, but when a man has used his total amount by the middle of July, it is hard to ruin his crop and see him suffer by refusing him any more water. The writer is of the opinion that the only way to handle this is to actually measure the water to each individual farmer, and charge him accordingly, with a graduated scale, which makes the third acre foot cost him considerable more than the first. There is at present being installed a system of drains which it is hoped will relieve conditions.

For the study of the ground water level there have been installed on this flat nearly 100 wells. Some of these are dug wells, owned by entrymen, but the majority are one inch galvanized iron pipe. A steel point is welded into the end, and holes drilled just above it.

LATERALS	DELIVERY IN ACRE FEET TO FARMS.							TOTAL ACRE-FEET DELIVERED TO FARMS FROM LATERAL.	IRRIGABLE LAND UNDER LATERAL.	ACRES IRRIGATED UNDER LATERAL.	ACRE-FEET PER ACRE FOR LANDS IRRIGATED
	APRIL.	MAY.	JUNE.	JULY.	AUGUST.	SEPT.	OCT.				
A						30.9	260.9	291.8	27 1/2.	285.00	1.03
B	6.7	711.1	1543.8	2160.5	1275.1	820.6	70.2	7218.0	3702	3414.00	2.11
C	20.6	644.5	864.6	1045.3	854.9	446.6	44.3	4020.8	3417	1819.00	2.21
D		400.0	540.4	675.2	760.5	182.0	360.1	2418.2	3417	911.00	2.66
E & E		150.4	305.0	450.0	304.3	239.8	75.3	1700.8	828	583.50	2.91
F		460.3	746.8	974.7	661.4	466.8	449.7	3759.7	1956	1641.00	2.29
D & F	5.7		22.6	166.4	92.3	94.2	65.5	446.7	262.	256.25	1.74
R	32.4	520.8	800.8	1115.9	565.3	374.8	448.0	3858.0	1911	1475.00	2.62
S	31.2	271.3	721.5	799.7	425.9	328.9	263.4	2841.9	2334	1728.50	1.64
T	17.8	364.2	576.3	606.0	469.6	192.0	403.7	2624.6	2455	1339.00	1.96
U & V	16.8	575.0	1047.0	1142.4	685.9	520.5	575.3	4562.9	4544	1705.00	2.71
W		358.	601.1	525.2	332.4	327.4	221.7	2043.6	3228	1058.00	1.93
TOTAL	126.2	4133.4	7769.9	9661.3	5627.6	4024.5	4444.1	35787.0	32766	16216.25	

WATER DELIVERY BEGUN APRIL 25, 1911.
" " DISCONTINUED OCTOBER 25, 1911.
ACRES IRRIGATED 16216.25
TOTAL ACRE FEET DELIVERED TO FARMS 35787.00
ACRE-FEET PER ACRE " " IRRIGATED LAND - 2.20
" " OF WATER WASTED BY FARMERS = 7547.00
" " " " RETAINED ON LAND - 28240.00
" " PER ACRE RETAINED ON LAND - 1.74

DEPARTMENT OF THE INTERIOR
UNITED STATES RECLAMATION SERVICE
SHOSHONE PROJECT WYOMING
WATER DELIVERED TO FARMS - 1911
DECEMBER 30, 1911

Drawn by J.K.
Traced " A.E.M.
Checked " C.M.J.

SUPERVISING ENGINEER

PROJECT ENGINEER

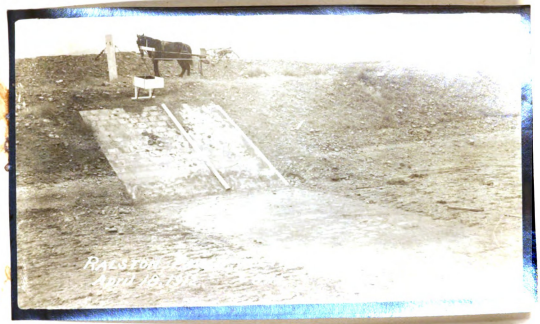
V-G. 2322

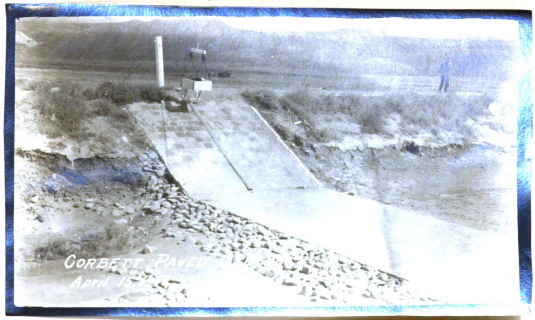
Which is the duty often assumed, this distributary should carry 2 second ft. If they all wanted water at the same time as they generally do, they could each have 0.5 Sec. ft. which is not enough for a man to use economically.
The quantity of water which an irrigator can handle to advantage depends on the charactor and topography of his land, and on his own personal equation. The writer, when in charge of the Operation and Maintenance on the Williston project, had on his division, some farmers who handled five sec. ft. without wasting a drop. Others could not care for one sec. foot. On porous ground a large quantity is necessary, in order to force it over all the land, as a small quantity will soak in close to the farm lateral, and seep away as fast as it comes, thus raising the ground water. There is being tried on some projects and advocated for others a system called the Rotation System, whereby half the farmers take water for a certain number of days and then wait the same number of days while the other half take it.

Referring again to drawing No. V-G-2322, the amount of water delivered to the farmers during the season, was as follows:

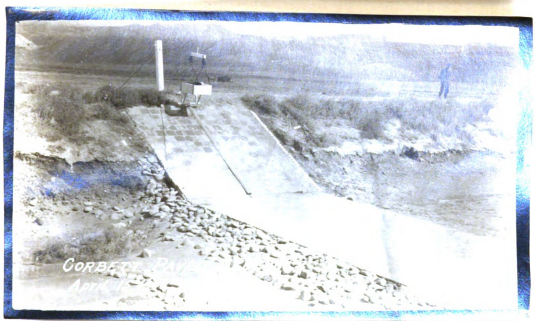
Month	Acre Ft. D'l'd.	Acre Ft. per Acre.	Depth in inches	Precipitation in inches	Total Water in inches
April	126.2	0.01	0.12	.98	1.10
May	4133.4	0.25	3.00	.80	3.80
June	7769.9	0.48	5.76	1.33	7.09
July	9661.3	0.59	7.08	.82	7.90
Aug.	5627.6	0.35	4.20	.51	4.71
Sept.	4024.5	0.25	3.00	.67	3.67
Oct.	4444.1	0.27	3.24	.39	3.63
Total	35787.0	2.20	26.40	5.50	31.90

In the above table, the acre feet delivered to farmers is taken from the drawing, and the precipitation is from the records of the rain gage shown in photo No. 21. The above 2.2 acre feet per acre, duty of water last season, is equivalent to 1 sec. ft. per 169 acres for the 186 days of the season, if it could have been distributed evenly over the entire season. The maximum flow past the Ralston paved section for the season was 285 sec. ft. on July 13. This, for the 16216 acres is one second foot per 57 acres. It is thought that this duty will be decreased as the farmers learn more about the use of water. The Wyoming State Law limits the water which may be appropriated for any project to one second foot for each 70 acres.





These additional photographs taken when the new gages were installed.




GAGE IN ALKALI CREEK FLUME.
April 18, 1912.
C.H.E.

ROOM USE ONLY