THE State Agricultural College OF COLORADO.

BULLETIN NO. 1.

REPORT

OF

EXPERIMENTAL WORK

IN THE DEPARTMENT OF

Physics and Engineering.

Fort Collins, Colorado, August, 1887.

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THE STATE BOARD OF AGRICULTURE.

Committee on Experiment Stations and Scientific Experiments:

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ANNOUNCEMENT.

At the semi-annual meeting of the State Board of Agriculture, held in June, the secretary was authorized by resolution, to have prepared and to publish reports of experiments conducted at the State Agricultural College, by the different departments, for free distribution.

In compliance with the resolution of the Board, the accompanying report from Professor Mead, of the department of Physics and Engineering on "Experiments in Irrigation and Meteorology" is herewith presented, in the form of Bulletin No. 1.

It is the design of the State Board of Agriculture to disseminate information from time to time concerning the experimental work carried on at the State Agricultural College, so that the character and progress of these scientific investigations, closely connected with agriculture and the related industries of the state, may be studied and utilized at the earliest opportunity by all who are interested in such subjects.

Copies of this bulletin may be obtained from the secretary on application.

FRANK J. ANNIS,
Secretary.

STATE AGRICULTURAL COLLEGE, FORT COLLINS, August 15, 1887.

REPORT

OF

EXPERIMENTS IN IRRIGATION

AND METEOROLOGY.

BY ELWOOD MEAD, B. S., C. E.,
Professor of Physics and Engineering.

INTRODUCTORY.

The object of this bulletin is to give an account of the experimental work for the present year of the department of Physics and Engineering, with the results obtained up to August 1. This work embraces meteorological observations, and experiments and investigations in subjects connected with irrigation. An increased knowledge of both subjects possesses for this state an exceptional interest and importance. The rapidity of the development of our irrigation interests by a people ignorant of the practice is without a counterpart, and has opened up many problems whose solution is urgently required, but which will require years of painstaking investigation. The study of our climate has both a commercial and scientific value. Greater attention is everywhere being paid to meteorological observations in connection with agricultural experiment work, but in this state the following facts lend additional importance to the work: We have a light rainfall and atmosphere of unusual dryness, solar and terrestrial radiation are very active, resulting in a considerable difference in temperature between day and night, while the number of hours of sunshine are nearly double that of some parts of the United States. The part that these exceptional conditions play in our agricultural successes and failures is worthy of attention.

While the settlement of all new countries produces a greater or less disturbance of existing conditions, the transformation wrought in the arid region by the development of its agriculture by irrigation is without a parallel. The wide spread belief that this has or is likely to result in a material change in our climate has aided in the agricultural development of the eastern part of the state where irrigation is not possible. The question of a change of climate can only be answered by careful observations running through a series of years. To give data for this work, as well as to obtain a record of the climate of some of the important agricultural districts of the state, auxillary stations were established the present season at Akron, Eastonville and Grand Junction. The first two being in the rain belt region, and the last on the western slope. The record for July appears in this bulletin. The rainfall record at Akron, is worthy of especial attention.

IRRIGATION EXPERIMENTS—DUTY OF WATER.

During the present season an accurate record has been kept of the volume of water used in the irrigation of two plats on the college grounds, in order to obtain data for an estimate of the "duty" of water. The college farm is not adapted to the conduct of experiments of this kind, the surface being uneven and the location of the numerous laterals such, that the area irrigated from each can not be clearly defined, an essential requisite. The original intention was to have one test consist in the measurement of the water on a field crop under ordinary cultivation; the other to be on the garden. In the test on field culture, however, I was restricted, by the difficulty before mentioned, to a portion of the experimental ground of Prof. Blount, composing 6.05 acres. This is divided up into plats of 42 rods, each planted with the various field crops, consisting of wheat, barley, oats and corn. The location of this plat is all that could be desired. The surface is even, with a gentle slope to the east. It is too high to be affected by seepage, the only water reaching it coming through the lateral where the measurements were made. The soil is stiff clay.

The record was kept by means of an automatic register, which recorded the depth of water passing over a weir placed in the lateral. The record after it was begun being continuous. The crest of the weir was of iron, filed true, and to a knife edge. In computing the discharge, the following formula was used:

Q=3.33 l h 3-2.

Q=Discharge in cubic feet per second.

L=Length on weir=17 inches.

H=Depth on weir in feet.

It is believed that the volume used is greater than that employed in ordinary irrigation, the watering of such small areas inevitably entailing considerable waste.

The soil of the college garden is a stiff clay, which has been loosened up somewhat by manures; it still, however, absorbs moisture very slowly. Nearly the whole of the garden has considerable slope, and in irrigating in furrows, from one-third to one-half of the water runs to waste. This fact should be kept in mind in considering tne volume required in its irrigation. The area of the plat is 2.1 acres; of this, .45 acre is experimental grasses and small fruits, the remainder being vegetables.

The water used on the garden was measured through a box invented by A. D. Foote, C. E., of Boise City, Idaho, the form of which is shown in the accompaning illustration, with the difference that the water passed out without pressure, the opening acting as a notch of adjustible width, the depth to remain constant. The depth of water passing through the box for April and May was fixed at six inches; after that at five inches. The form of the box is such that the regulation of the depth is very nearly automatic.

It was found that when the notch was more than two inches wide, the water in the lateral leading from it offered an obstruction to its free discharge. When the notch was six inches wide, the water in the lateral was about one inch above the bottom of the notch. A theoretical computation of the discharges under these conditions was not considered reliable, and a series of tests were made to determine this. The limits of this bulletin will not permit of a description of these tests, from which the following table of discharges was constructed:

Table Giving Discharges per Second and per Hour of the Measuring Box of College Garden Lateral.

Width of Notch in Inches.	Depth of water in inches.	Discharge per second in cubic feet.	Discharge per hour in cubic feet.
One-half	5	0.0450	162 00
One	5	0.0891	3 0.76
One and one-half	5	0.1153	415.08
Two	5	0.1515	545.40
Three	5	0.2202	792.72
Four	5	0 2889	1040.04
Five	5	0.3580	1288.80
Six	5	0.4271	1537.56
One	6	0.11623	418.33
One and one-half	6	0.16571	596.51
Two	6	0.21519	774 68
Three	6	0 29991	1079.67
Four	6	0 38463	1384.58
Five	6	0.47819	1721.48
Six	6	0.57176	2058.34

Table Giving the Dates of Irrigation and Quantity of Water Used in Irrigating the College Garden to August 1, 1887.

Date.	Number of hours run.	Width of notch in inches.	Volume discharged—cubic feet.	Total disch. for month—cubic feet.	Duty one cu. ft. per second—acres.
April 23	5 6	1	348.650	....	....
" 29	2½	6	5145.840	5494.49	....
May 1	3½	2	2506.245	....	....
" 6 to 7	14	3	15115.464	....	....
" 7	8	5	13771.872	....	....
" 9	4½	3	4858.542	....	....
" 9 to 10	13	5	22379.292	....	....
" 17	24	1½	7943.368	....	....
" 19 to 22	65	1½	36 83.080	....	....
" 25	4	1½	2269.728	105927.59	71.4
June 6	2½	1½	1082.700	....	....
" 8 to 11	72½	5	93438.000	....	....
" 11 to 12	19	3	14959.05	....	....
" 12 to 13	26¾	1½	115 4.89	....	....
" 13 to 16	78¼	½	12676.50	....	....
" 19 to 22	78	3	61832.16	....	....
" 22 to 24	50	1½	21654.00	217227.33	25.1
July 6	17	1½	7056.36	....	....
" 7 to 9	47	2	25633.80	....	....
" 9 to 12	83	3	65795.76	....	....
" 26 to 29	83	3	65795.76	....	....
" 30 to 31	27	3	21403.44	1856 5.12	30.3

**Table Giving Dates of Irrigation and Quantity of Water Used in Irrigating Experimental Plat on College Farm From June 1 to August 1, 1887.*

Date.	Number of hours run.	Mean depth on weir.	Volume discharged—cubic feet.	Total discharge for the month—cubic feet.	Duty one cu. ft. per second—acres.
June 1 to 6	144	2¼	204505.344	....	....
" 7	24	2	27124.128	....	....
" 8	24	2	27124.128	....	....
" 14	24	¾	6558.336	....	....
" 15	24	¾	6558.336	....	....
" 16	24	¾	6558.336	....	....
" 17	24	½	3570.768	....	....
" 20	24	¼	1261.152	....	....
" 21	12	¾	3279.168	....	....
" 22	15	¾	4098.960	....	....
" 23	11	¾	3005.904	....	....
" 24	18	7	5267.204	297911.764	52.7
July 5	24	¾	6558.336	....	....
" 6	24	1½	18553.392	....	....
" 7	24	1½	18553.392	....	....
" 8	24	1½	18553.392	....	....
" 9	12	1¾	11617.560	....	....
" 10	24	1¾	23235.120	....	....
" 11	24	2	27124.128	....	....
	8	2	9041.376	....	....
July 12	16	1	6732.576	....	....
	8	2	9041.376	....	....
	2	1½	1546.116	....	....
July 13	14	¾	3825.696	....	....
	11	1½	8503.638	....	....
July 14	13	¾	3552.482	....	....
" 15	24	1½	18553.392	....	....
" 16	24	½	3570.768	....	....
" 17	24	¼	1261.152	....	....
" 18	24	¼	1261.152	....	....
" 19 to 20	48	½	7141.536	....	....
" 21 to 23	72	1	27256.592	....	....
" 24	24	1½	18553.392	....	....
" 25	24	1¼	12969.296	....	....
	10	1¼	5820.540	....	....
" 26	14	1	5891.0[illegible]	....	....
	12	1	5[illegible]49.432	....	....
" 27	12	¼	630.576	....	....
" 28	24	½	3570.768	....	....
	9	½	1339.028	....	....
" 29	2	¼	105.096	230422.624	57.7

*Owing to a delay in the completion of the register, the record was not begun until June 1. Irrigation began about the middle of May.

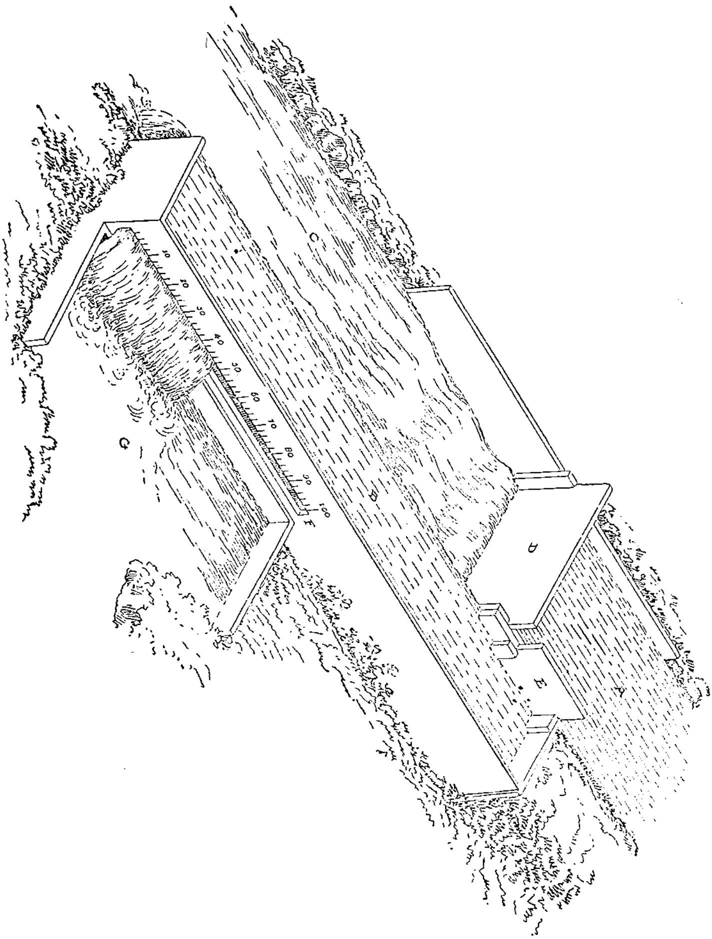
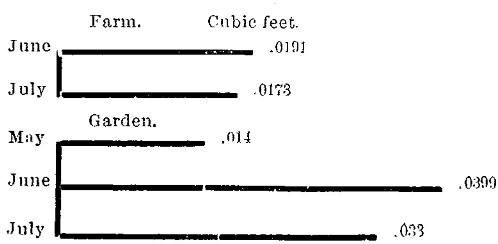


Diagram Illustrating Volume of Water Required.



NOTE—Length of line indicates the volume per second per acre.

ATMOSPHERIC EVAPORATION.

The record of the amount of evaporation from an exposed water surface has been continued since September, 1886. Since March 1st, of the present year, the record has included the loss for each day and hour of the day, an automatic register tracing the descent of the water surface by a pencil line on graduated paper. The register has thus not only served as an evaporometer, but as a rain guage as well. This continuous record, taken in connection with the meteorological observations of the College, has afforded an opportunity for studying the atmospheric influences which most affect the rate of evaporation, and as very little has been written on this subject, the principal causes will be stated:

The amount of vapor in the atmosphere.

The temperature of the air and water surface.

The pressure of the atmosphere.

Velocity of the wind.

Extent of water surface.

The diminished pressure of the atmosphere, at Fort Collins between one-fifth and one-sixth less than at sea level, tends to render the rate of evaporation excessive, as does the small amount of moisture in the air. Western winds increase evaporation by diminishing the amount of vapor in the air.

The box employed for holding the water was three feet square and two and one-half feet deep, sunk in the ground in an exposed place and kept filled with water to within six inches of the top. The small area of its surface would tend to make the rate of evaporation greater than from a reservoir, but this was compensated by the obstruction to the full effect of the wind.

Laying aside the disturbing actions of winds, the rate of evaporation depends on the difference between the force of vapor in the air and the maximum force of vapor for the temperature of the water surface, or it will be sufficiently accurate to say that other things being equal, the rate of evaporation bears a direct ratio to the difference between the temperature of the water surface and the dew point. When farthest apart, evaporation will be most rapid, and when together, it will cease.

The greatest recorded evaporation for twenty-four hours, was from noon, March 31st, to noon, April 1st, and was .4 inches. It was during the prevalence of a western, or "chinook" wind, which had already lasted two days. The mean temperature of the water surface was 53 degrees, and the mean dew point 9½ degrees. During the months of March and April, evaporation was very irregular, being greatest between the hours of 2 and 6 p. m., while frequently for several days there would be no perceptible loss. Since May, evaporation has gone on as rapidly during the night as during the day. The explanation which suggests itself is this: Irrigation began on the grounds surrounding the evaporation apparatus in May. During the day, when evaporation would otherwise be most rapid, the air is loaded with moisture by evaporation from the saturated soil. At night, owing to its more rapid cooling, evaporation from the soil ceases sooner than from the tank. To illustrate this, I have chosen a day at random, which happened to be July 23rd. The dew point for the hours of 7 a. m., 2 p. m. and 9 p. m., were 51, 62 and 55 degrees, respectively, and the temperature of the water surface for the same hours was 68, 82 and 74 degrees. The difference between the two temperatures, on which the rate depends, was respectively, 17, 18 and 19 degrees, showing that at 2 p. m. and 9 p. m. the rate should have been, and was, the same.

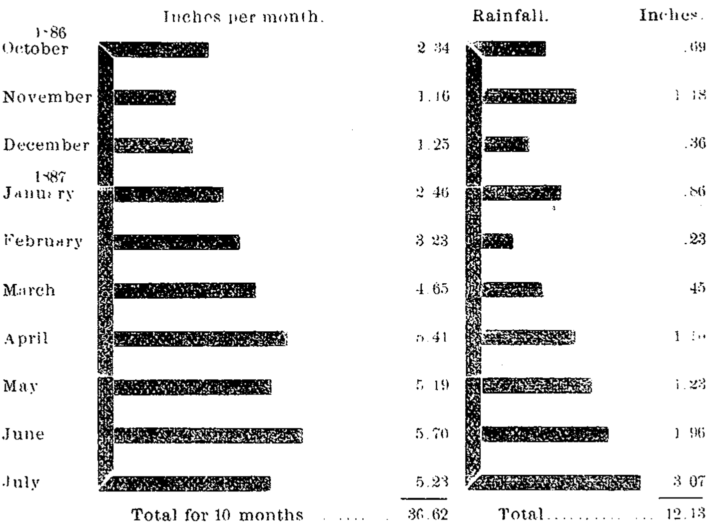
It is not probable that our mountain streams suffer any appreciable loss from evaporation, as their mean temperature is usually below that of the mean dew point. To test this matter, daily observations were taken at Fort Collins, of the temperature of the water of the Poudre River during June and July. For June, the mean temperature of the water was 59 degrees, while the mean dew point was 63 degrees. For July, the mean water temperature was 63, and the mean dew point 59 degrees. So that in the vicinity of Fort Collins, the river probably gained by its contact with the air during June, and lost during July. Below Fort Collins the increasing temperature of the water would cause the loss to be greater, while above, the reverse would be true.

The loss in canals varies with their location, size and velocity. The main loss from this source comes, however, after the water reaches the laterals here, and in flowing over the heated ground in irrigation the temperature is soon raised to a point where evaporation is greater than any here recorded.

That irrigation materially increases the humidity of our climate during the summer months is, I think, susceptible of proof.

Irrigating the ground surrounding the meteorological instruments sensibly affected the readings of the wet bulb thermometer, and I am confident that if the evaporation box had been situated anywhere in this vicinity outside the irrigated area, the loss for July would have been much greater. That any increase of the irrigated area will result in an increased rain fall for that area, is not to be believed, as owing to winds, rains seldom or never fall where their moisture is collected. Whatever change may be produced will be most likely to affect the country to the east of us, owing to the prevalence of western winds. During the months of June and July, the atmosphere takes up from the surface of the Poudre district at least one thousand cubic feet of water per second. Add to this the amount from the other districts, and it will be seen that several rains for some more favored region, accumulate on the Platte and its tributaries during the season.

Diagram Illustrating Evaporation Record.



NOTE—Observations continued for four years of the rate of evaporation from a box four feet square, three feet deep, near New York City, gave a mean annual evaporation of 24.15 inches, the mean annual rainfall for the same time being 40 inches.

METEOROLOGICAL OBSERVATIONS.

The last report of this department gave a summary of the observations for the year, to June 1st. Only a few of the more important facts of the subsequent record, therefore, will be given in this bulletin.

The following instruments have recently been added to the equipment of the station: Self registering barometer and thermometer, solar and terrestrial radiation thermometers and sunshine recorder.

From the record of the registering thermometer, the coldest period at night is between 5 and 6 a. m., the temperature falling steadily to that hour. The hour of maximum temperature is not so well defined, but is usually about 3 p. m. The mean maximum temperature for June and July was 84 degrees, and the mean minimum temperature 53 degrees, giving a mean daily range of 31 degrees.

The mean maximum temperature in the sun was 148 degrees, or 64 degrees above that of the shade. The mean temperature of the terrestrial radiation thermometer was 45 degrees, or 8 degrees below the mean minimum.

Temperature and Rainfall Record for July.

Station.	Max temperature...	Min. temperature...	Mean temperature.	Relative humidity..	Days of rainfall....	Total rainfall-inches	Name of Observer.
Akron...........	100	60	72	58	7	6.1	Vance & Stephenson...
Eastonville........	96	46	67	76	20	4.02	J. C. Plumb. ....
Grand Junction....	98	64	76	[illegible]	8	2.23	Dr. L F. Ingersoll......
Fort Collins.......	97	50	69	69	9	3.07	....