1970 Annual Report
to
Agricultural Research Service
Boise, Idaho

30

WATER RESOURCES RESEARCH INSTITUTE

WATER for IDAHO

WATER BALANCE ON A UNIT SOURCE AREA IN SOUTH FORK PALOUSE RIVER

Water Resources Research Institute
University of Idaho
Moscow, Idaho 83843

Water Balance on a Unit Source Area in South Fork Palouse River

Personnel:

Myron Molnau and D. J. Davis, Idaho Water Resource Research Institute, University of Idaho, Moscow, Idaho.

Objectives of the present study:

Within the overall objectives of Project SWC 2-f3, the following were selected for immediate study:

1. To set up the instrumentation necessary for making a rough water balance.
2. Collect data and make a preliminary water balance.
3. Begin collecting data for studies of erosion and soil temperature profiles.

Variables under Investigation:

1. Precipitation versus time
2. Surface runoff versus time
3. Soil moisture content
4. Temperature and humidity of air
5. Solar radiation
6. Pan evaporation, water temperature, and wind movement
7. Sediment yield

Experimental Data, Instrumentation and Observations:

All data obtained during the 1969-70 water year has been appended to this report. Incomplete data was collected for many variables either due to lack of instrumentation or lack of need for data during those parts of the year.

Temperature and humidity were measured with a hygrothermograph. Recorded temperatures were checked using maximum and minimum thermometers. The average daily temperature used is the average of the daily maximum and minimum values. Recorded humidity was checked using an aspirated psychrometer each time the chart was changed. The mean daily humidity was obtained by averaging the area under the recorded curve for each day. All values for humidity were read to the nearest 2%, and any analysis using this data should not attempt greater accuracy.

Precipitation was measured during the entire water year by two Bendix recording precipitation gauges (one shielded, the other unshielded). However, the data from these gauges has not been made available by the ARS office in Boise as of the time of this report. A standard type rain gauge was set up at the central instrument cluster providing data for the last month of the water year. In order to proceed with a very rough water balance it is necessary to estimate precipitation based on data collected at the University of Idaho station (four miles to the southwest). A separate study is now underway to relate precipitation at the Thompson Watershed to that at these other stations. When the data from the shielded and unshielded gauges are available, the data will be used.

Surface runoff is measured with a Stevens water level recorder on a drop-box weir. Considerable difficulty has been encountered in keeping runoff from the access road out of the weir. The float was frozen several times during the runoff in January and February which limited the amount of valuable hydrograph data. Only three flow measurements were obtained during this period which were used to adjust the stage-discharge rating of the drop-box. An attempt was made to estimate a reasonable average daily stage from which a daily runoff estimate could be calculated for the watershed.

Sediment samples are obtained by a grab technique, since the depth of flow is not deep enough to require depth integration (0.30 ft). Because of the short runoff period and problems getting to the watershed, sediment concentration for only four days could be determined. (See Table 1.) Work during the spring concentrated on perfecting a gravity sediment sampler for use with the drop-box weir. Two samplers were constructed. One has been delivered to the Northwest Watershed Research Center for use at Reynolds Creek and the other installed at the Thompson Watershed. A paper was presented about this sampler (Johnson and Molnau, 1970) and a short description of the sampler is appended to this report.

Soil moisture content was measured by gravimetric methods every two weeks during July, August and September. Moisture samples were taken at 6-inch intervals down through the soil mantle to a tight clay layer that is encountered at from 30 to 36 inches below the surface depending on the location on the field. The three sampling locations used were chosen to give an approximate uniform representation of the watershed. During the next year samples will be taken at six locations using a neutron probe.

A standard four-foot diameter pan is used to measure evaporation. A Stevens water level recorder gives a continuous record of the water level in the pan. The recorder float is located in a 16-inch diameter culvert which is attached to the pan by a section of 2-inch pipe. It is suspected that the evaporation rate from inside the covered culvert might be sufficiently different from the pan to cause a consistent error in the evaporation data. After the third week in September the evaporation rate was reduced enough to justify turning the pan over for winter. Later examination of data from the University of Idaho station showed a significant amount of evaporation during the following five weeks. This area seems to be affected by an "Indian Summer" with warmer temperature and dry winds of moderate speed that follows the first cold waves in September (see attached graphs). Therefore, the evaporation pan should be kept in operation until the end of October or after several weeks of freezing temperatures. A separate study is being made to correlate evaporation parameters at Thompson with that at the University station.

Water temperature and wind movement were measured in conjunction with evaporation. A 24-point Honeywell recorder with Type J thermocouples was used for hourly measurements of water temperature in the evaporation pan. For several weeks daily checks of the recorded temperatures was made using a maximum-minimum mercury thermometer in the pan. Wind distance was recorded on an Esterline-Angus event recorder, from which miles per day could be obtained.

Solar radiation is needed for using the Jensen-Haise method to determine evapotranspiration. An Eppley radiometer is coupled to a Bristol recorder to measure radiation. Another channel is available on this recorder for the measurement of heat flux in the soil. Trouble with one channel of this recorder prevented continuation of heat flux measurements after only a few days of data had been collected during June.

Comments, Interpretations and Future Plans:

The primary objective this year was to get the instrumentation and data collection procedure set up to do a water balance. Only a very rough water balance is possible at this time since much of the data is incomplete.

The basic water balance formula can be simplified to $P = Q + ET + \quad S$, where P is precipitation, Q is surface runoff and ET is evapotranspiration. The term S is a composite of all the factors for which no measurements were made during this water year, and includes the change in soil moisture storage, deep percolation to ground water storage and subsurface runoff.

Precipitation is estimated to be 30 inches or slightly higher than the 28 inches measured at the University station. The Thompson watershed is located nearer to the base of Moscow Mountain and should receive more precipitation due to the effect of orographic lifting of storm air masses. Surface runoff of 5 inches was measured during the months of January and February. The Jensen-Haise formula was used to determine ET for only part of the growing season (June 19 to August 8) and the very high 19 inches computed for this period has to be rejected from this analysis until better crop coefficients can be determined. A more reasonable value of 16 inches for the average annual consumptive use for spring grains at Moscow was obtained from Sutter and Corey (1970). If the values estimated above are used in the basic water balance formula a value of 9 inches results for

S, the unseen subsurface water movement and change in storage.

As a check on this value of S, the following reasoning may be applied: The soil profile shows a restrictive layer below the three-foot depth as an average for the watershed. The soil mantle above this layer allows ample room for good root development for barley or other small grains.

Let us accept the high moisture holding capacity of 3.4 inches per foot available moisture determined from data collected by Earl Neff (1966). The root zone of 3.0 feet on the average should be able to hold 10 inches of stored available moisture from winter precipitation. The total precipitation through the end of April (when consumptive use begins) was estimated at 22 inches. Since 5 inches were lost in the root zone the remaining 7 inches must have gone to deep percolation. Precipitation during May was nearly 3 inches, of which it is reasonable to expect 2 inches loss in ET and 1 inch left for deep percolation.
Precipitation during May was nearly 3 inches, of which it is reasonable to expect 2 inches loss in ET and 1 inch left for deep percolation.
The 8 inches in deep percolation obtained from this analysis is in good agreement with the 9 inches obtained for S in a previous paragraph. It must be borne in mind that this is only a preliminary water balance and therefore all values used are carried to only one significant figure.

Since there is little rain in July and August the root zone will be depleted of most available moisture at this time each year. Therefore, very little moisture will be involved in change in storage in the soil mantle and the two variables of significance for S are the change in ground water storage and subsurface flow from the watershed. The two observation wells might provide information that will allow computation of both of these variables, if the wells can be made to function properly. No maintenance over the past three years has resulted in very dubious response of the wells to water level changes.

During the next water year emphasis will be placed on improving the data collection methods and obtaining complete (or nearly complete) records. The result of this more exacting and complete data should provide a better picture of the water balance on this watershed. Detailed computation and analysis methods will be provided in the Master thesis which is scheduled for completion at the end of the Fall Semester 1971-72.

REFERENCES

Neff, Earl L. Some soil characteristics of a small agricultural watershed. Unpublished paper for a course in soil science, University of Idaho, 1966.

Sutter, R. J. and Corey, G. L. Consumptive irrigation requirements for crops in Idaho. Bulletin 516, College of Agriculture, University of Idaho, 1970.

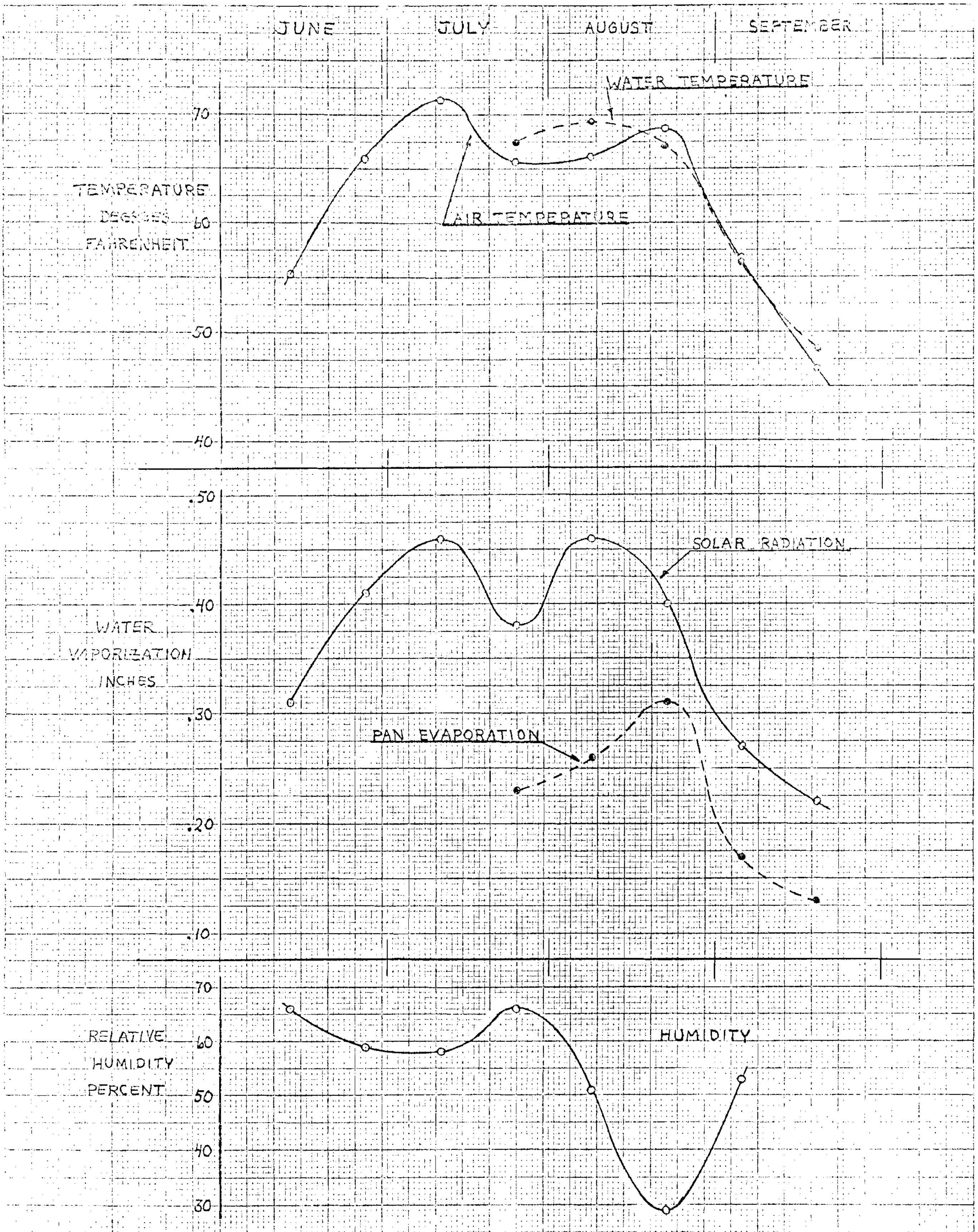
Johnson, C. W. and Myron Molnau. A gravity sediment sampler for drop box weirs. Paper presented at the annual meeting of the Pacific Northwest Region meeting of ASAE at Bozeman, Montana, October 7-9, 1970.

Appendix 1

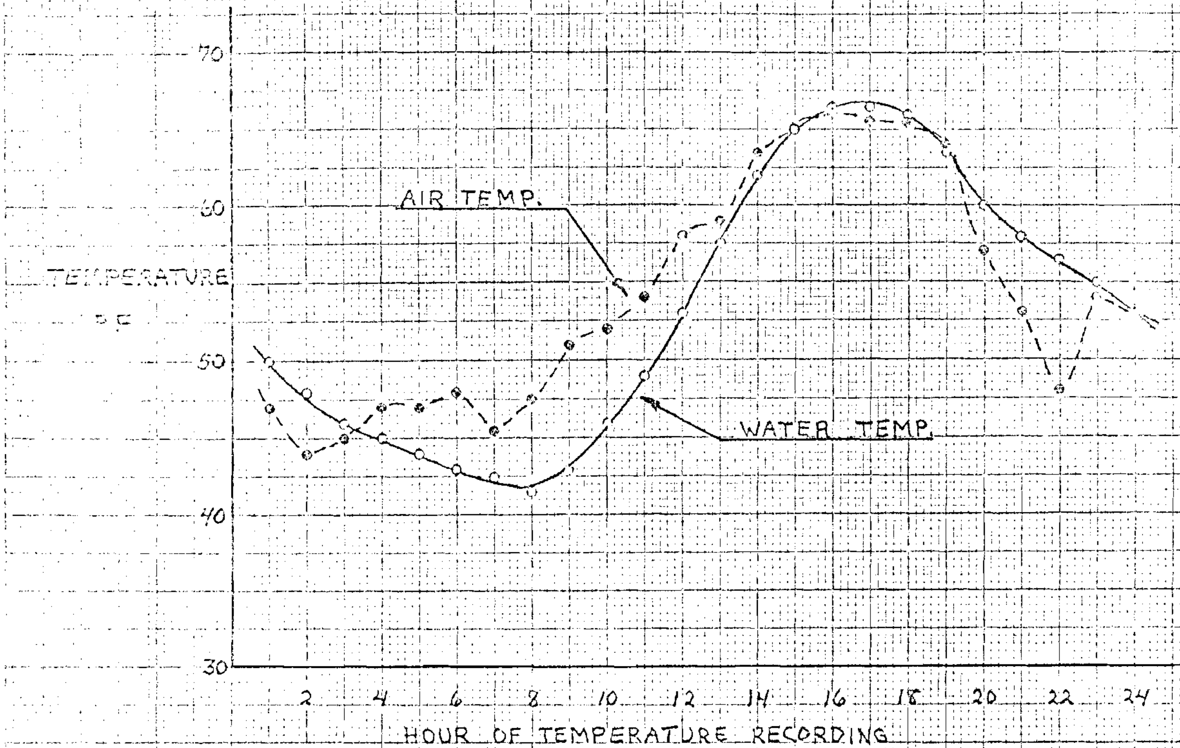
Basic Data

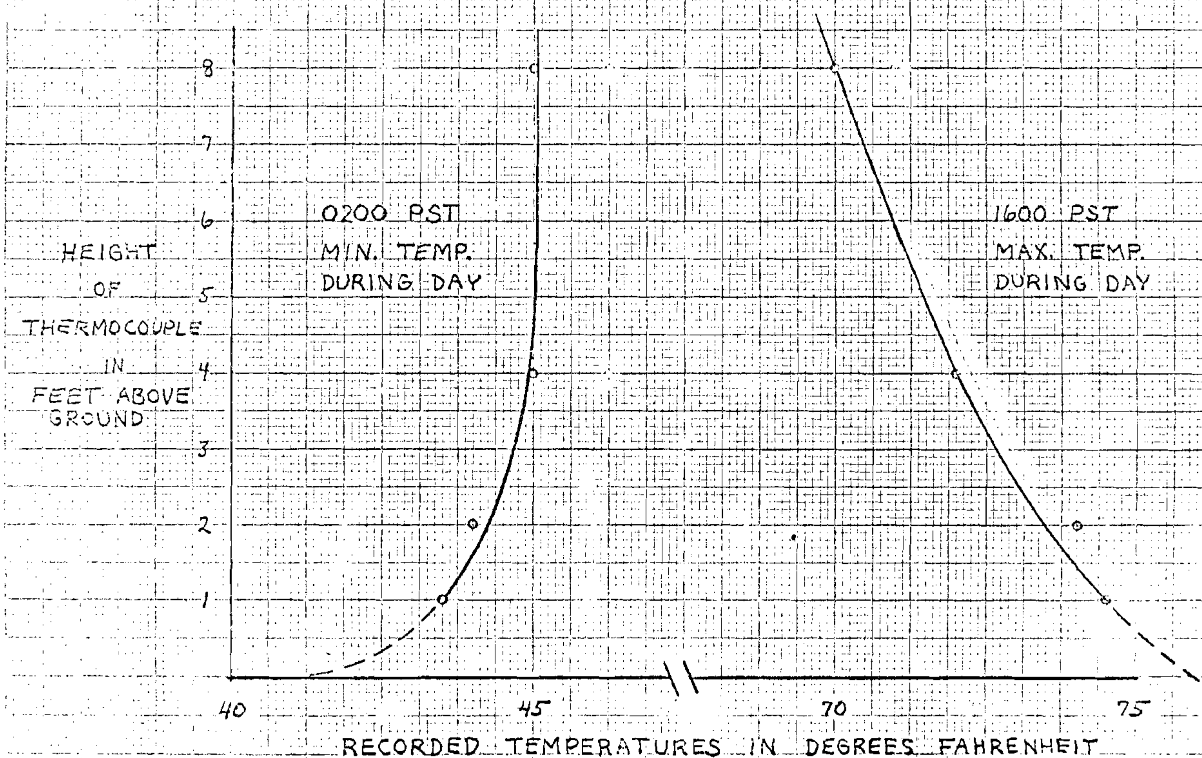
Table 1. Runoff Summary from a January Snowmelt Period

Date	Mean daily discharge (cfs)	Mean sediment concentration (mg/l)	Erosion loss (tons/acre)
Jan. 23	.15	800	.040
24	.15	--	--
25	.10	70	.002
26	.046	--	--
27	.080	70	.002
28	.030	25	.0003



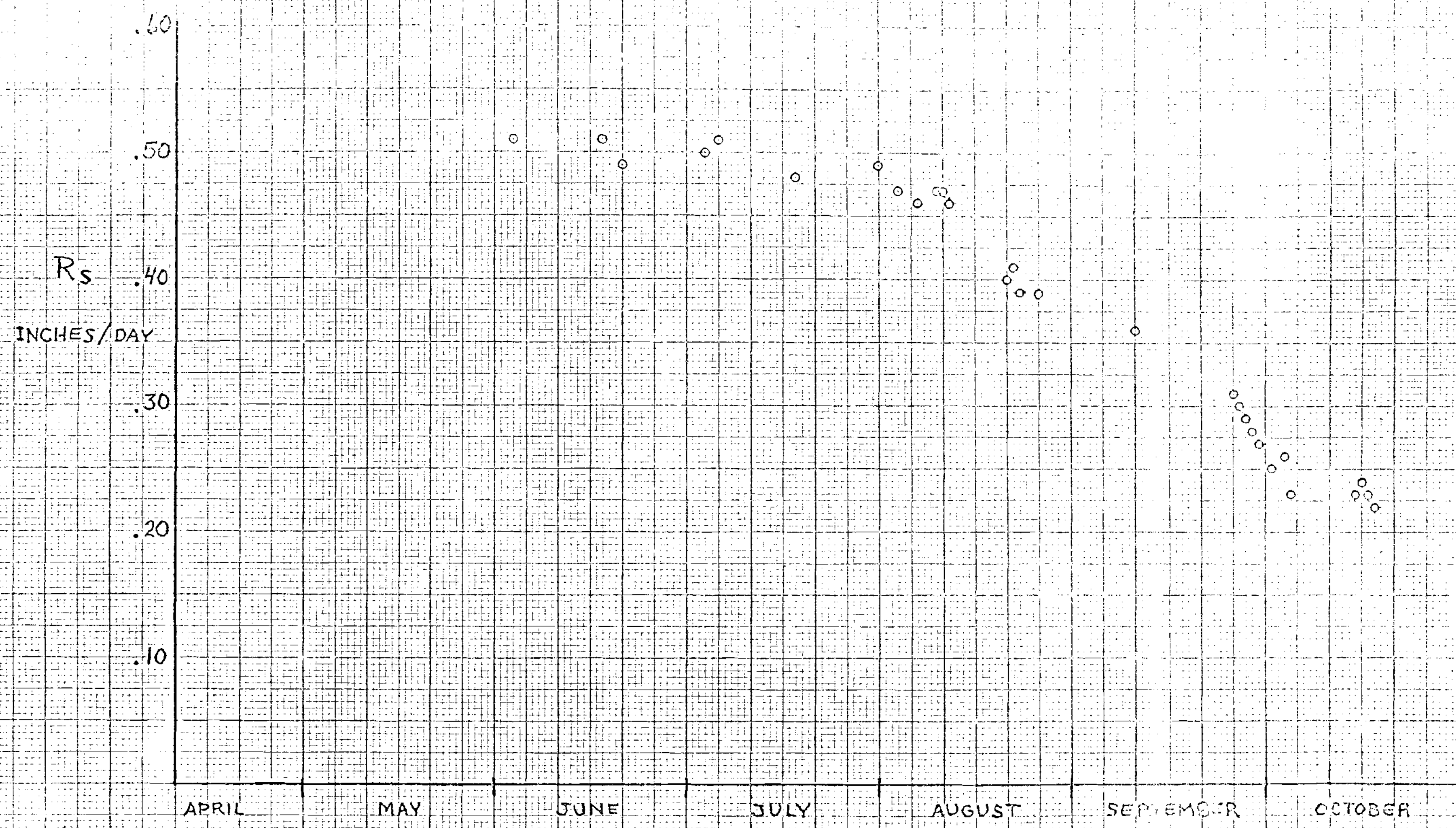
COMPARISON OF AIR TEMPERATURE, WATER TEMPERATURE, PAN EVAPORATION, SOLAR RADIATION AND RELATIVE HUMIDITY AT THE THOMPSON WATERSHED. EACH PLOTTED POINT REPRESENTS THE AVERAGE OF A TWO WEEK INTERVAL. SUMMER 1970.



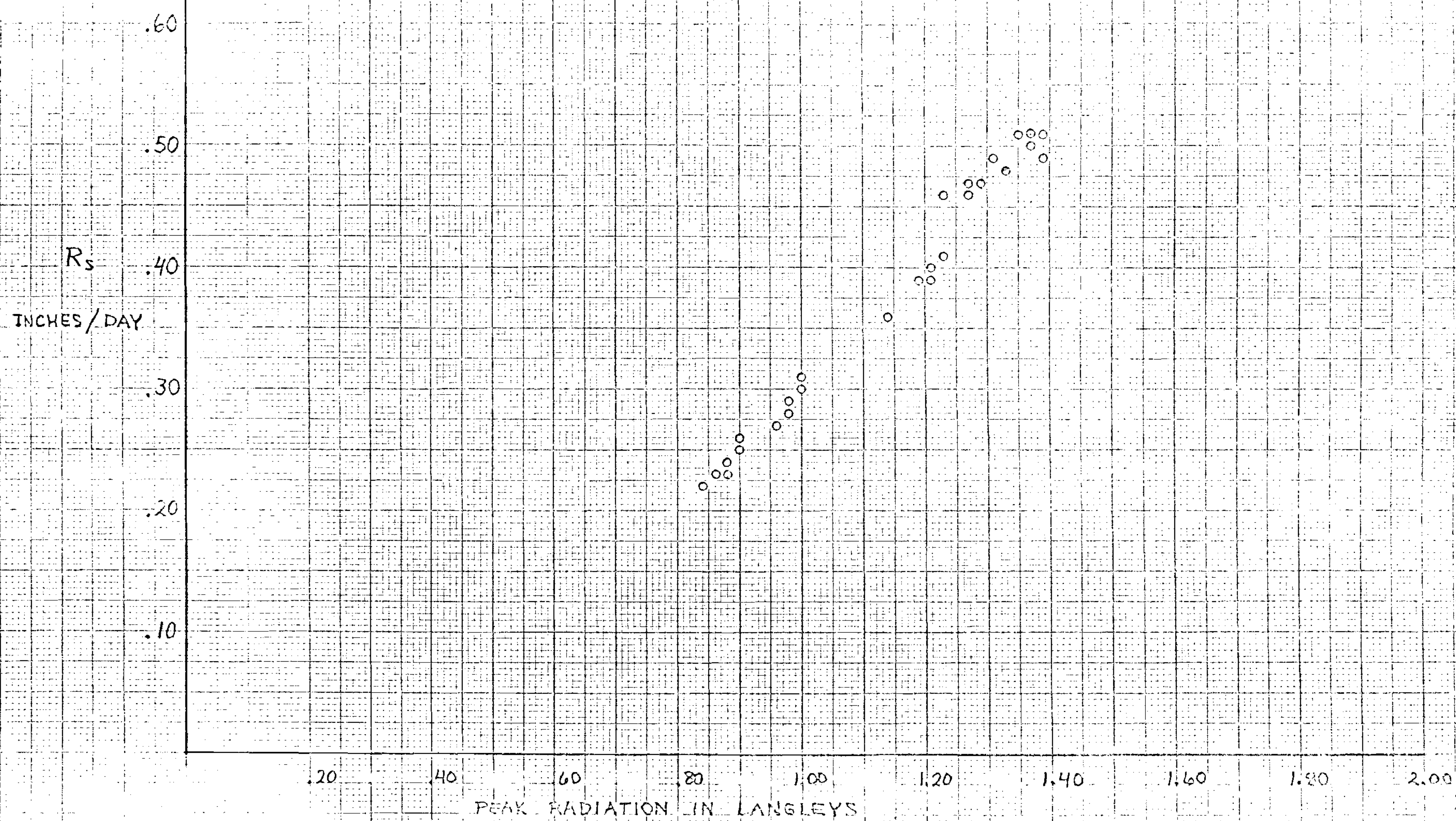


TEMPERATURE PROFILES AT THOMPSON WATERSHED, MOSCOW
TAKEN ON 10 SEPTEMBER 1970 AS TYPICAL OF CLEAR SKYS.

12-188
5788

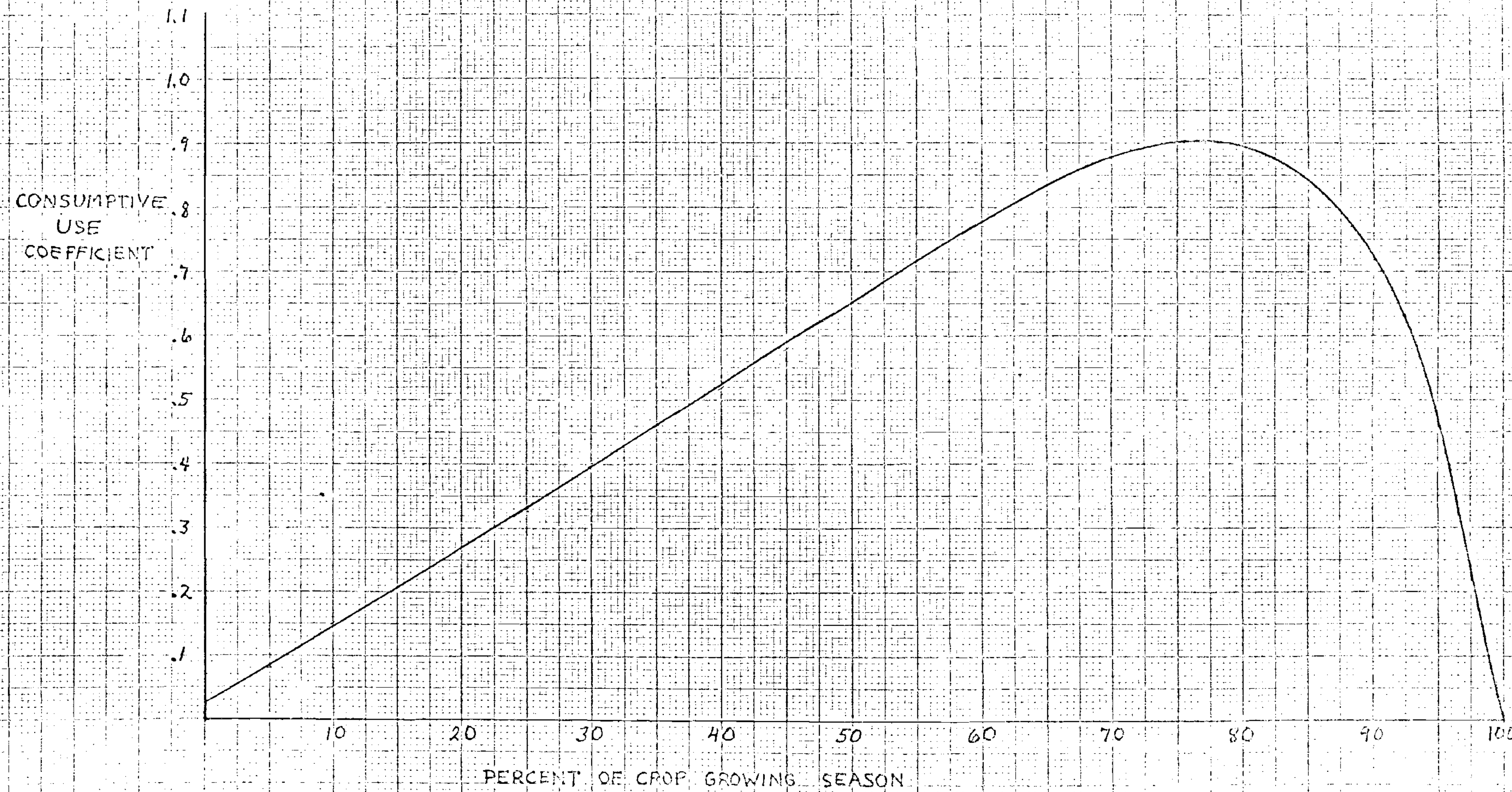


TOTAL DAILY SOLAR RADIATION IN INCHES PER DAY OF EQUIVALENT WATER VAPORIZATION FOR CLEAR DAYS AT THE THOMPSON WATERSHED, MOSCOW, IDAHO.

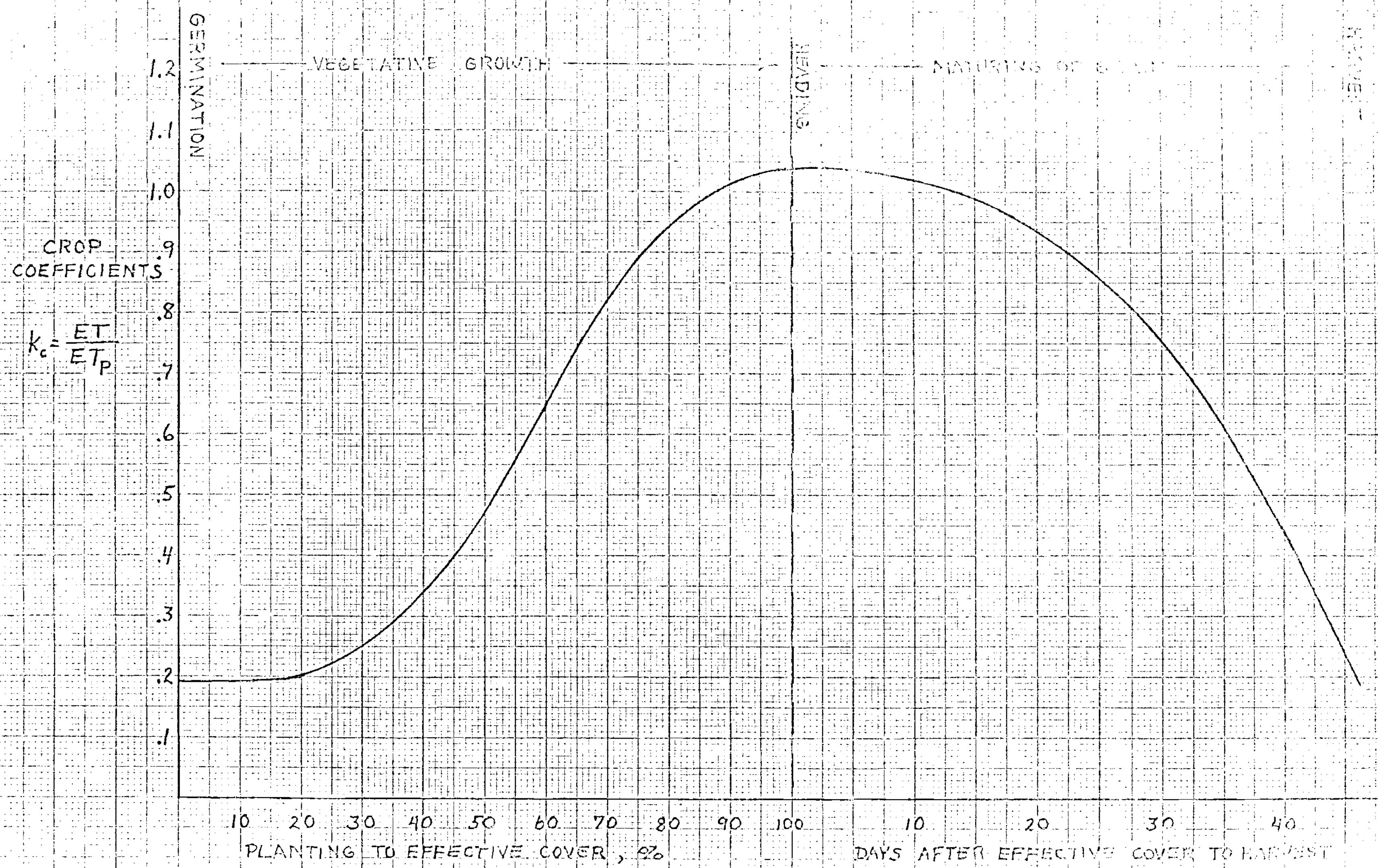


TOTAL DAILY SOLAR RADIATION AS A FUNCTION OF PEAK RADIATION DURING THE SAME DAY FOR CLEAR DAYS AT THE THOMPSON WATERSHED, MOSCOW, IDAHO.

12-188
5768



CONSUMPTIVE USE COEFFICIENTS TO BE MULTIPLIED BY CLASS A PAN EVAPORATION OR CALCULATED Ep.
HARGRAVES, G.H. COMSUMPTIVE USE COMPUTATIONS FROM EVAPORATION DATA. Paper Presented at ASCE Conference on Irrigation and Drainage, Las Vegas, Nov. 1966.



CROP COEFFICIENTS FOR SMALL SPRING GRAINS AT ALL STAGES OF DEVELOPMENT.
From Chapter Five, Sprinkler Irrigation (Third Edition).

RUNOFF IN INCHES (1969-1970)

Thompson Watershed, Moscow 1/

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1				---	.01							
2				---	.01							
3				---	.01							
4				---	.01							
5				---	.01							
6				---	.01							
7				---	.01							
8				---	.05							
9				---	.03							
10				---	.02							
11				---	.01							
12				---	.01							
13				---	.06							
14				---	.15							
15				---	.15							
16				---	.28							
17				---	.27							
18				---	.07							
19				.01	.05							
20				.17	---							
21				.90	---							
22				.17	---							
23				.45	---							
24				.45	---							
25				.30	---							
26				.14	---							
27				.24	---							
28				.09	---							
29				.06	---							
30				.04	---							
31				.02	---							
TOTAL				3.04	2/							

1/ A calculated area of 8 acres was used to compute depth of runoff.
2/ Some runoff occured during the last two weeks in February but the records are missing. Therefore a value of two inches is estimated for the month.

MEAN DAILY RELATIVE HUMIDITY (1969-1970)

Thompson Watershed, Moscow 1/

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	90	90	92	91	86	92	69	59	--	56	68	39
2	81	81	91	90	77	90	67	52	--	62	84	--
3	75	85	90	85	77	88	57	37	36	58	65	--
4	70	80	99	92	74	86	58	31	52	60	53	78
5	60	98	92	74	67	79	66	55	--	55	56	81
6	47	93	87	66	98	81	70	78	--	46	48	63
7	43	90	96	57	80	89	66	83	--	49	50	78
8	70	72	89	56	80	82	62	84	--	54	51	56
9	72	82	98	91	76	72	75	75	72	57	42	52
10	79	92	87	--	88	56	72	73	64	66	35	45
11	60	92	82	--	90	70	68	57	59	56	36	--
12	28	--	90	87	77	83	--	87	57	57	34	--
13	32	--	76	90	100	76	--	80	57	88	48	--
14	43	--	83	88	89	90	--	63	88	65	45	--
15	42	--	81	87	85	82	--	45	82	59	38	--
16	50	86	68	95	79	88	--	40	70	45	36	--
17	70	86	78	92	82	76	--	55	55	57	38	--
18	86	63	90	100	83	75	58	30	60	59	42	--
19	78	--	90	97	75	62	92	52	62	51	36	--
20	76	--	90	90	60	60	87	--	57	51	32	--
21	69	88	95	92	64	76	79	--	67	59	24	--
22	59	78	82	93	76	72	77	70	52	60	23	--
23	84	72	89	97	80	69	71	70	60	63	18	--
24	93	77	89	95	70	58	78	--	58	54	18	--
25	86	75	80	88	71	63	83	--	52	87	--	--
26	47	80	98	89	73	57	74	--	53	75	26	59
27	76	70	92	88	75	62	80	--	80	79	25	54
28	100	88	88	89	58	82	70	--	55	92	26	47
29	88	70	90	69	--	82	72	80	62	62	36	48
30	85	63	95	66	--	45	66	74	57	70	24	55
31	97	--	94	84	--	48	--	50	--	68	31	--
AVG	68.9	81.3	88.4	85.4	78.2	73.9	71.5	61.7	61.1	61.9	39.6	58.1

1/ Mean daily relative humidity determined from area under the 24-hour continuous recording.

AVERAGE DAILY TEMPERATURE (1969-1970)

Thompson Watershed, Moscow 1/

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	47	46	28	14	33	25	39	50	62	60	72	63
2	45	46	27	22	33	23	41	55	--	67	62	60
3	46	45	25	21	32	27	37	52	72	74	64	57
4	49	47	28	10	29	30	43	63	68	77	76	45
5	45	44	28	15	33	28	48	--	71	73	75	51
6	52	43	30	17	34	36	44	--	--	68	74	58
7	55	43	29	20	41	38	33	--	--	71	66	56
8	49	44	28	29	41	36	40	45	--	73	60	48
9	46	38	29	33	42	33	43	44	51	76	61	49
10	45	42	29	26	39	39	37	40	47	73	67	57
11	42	43	35	26	38	37	--	41	50	69	--	49
12	36	--	36	31	43	38	--	42	51	70	--	44
13	36	--	40	37	33	43	--	41	57	60	--	42
14	38	--	38	38	37	40	--	48	52	67	62	41
15	39	--	35	34	38	42	--	59	50	71	69	46
16	44	31	34	28	40	36	--	68	53	82	70	49
17	47	31	37	24	35	35	--	56	63	69	63	61
18	43	33	38	32	35	38	--	56	65	72	60	51
19	42	39	37	37	38	38	--	58	69	77	67	50
20	51	42	--	38	40	40	34	66	69	74	70	44
21	55	39	--	38	43	40	38	58	74	66	69	48
22	61	36	35	39	41	40	39	59	74	62	74	48
23	51	35	36	38	40	38	40	58	74	64	76	43
24	45	35	32	36	39	39	38	59	71	66	80	42
25	42	36	32	32	42	37	36	64	70	58	69	44
26	46	34	29	33	41	40	37	--	78	70	65	52
27	42	--	21	33	34	42	41	--	59	72	67	61
28	41	30	20	29	30	42	43	--	55	58	64	66
29	42	31	26	27	--	39	40	48	47	60	61	66
30	45	34	27	33	--	39	45	51	51	57	70	59
31	48	--	19	31	--	41	--	57	--	63	72	--
AVG	45.6	38.7	30.6	29.1	37.4	36.7	39.8	53.5	61.7	68.4	68.0	52.7

1/ Average daily temperature is the average of the maximum and minimum daily temperature.

TOTAL DAILY SOLAR RADIATION, INCHES OF WATER (1969-1970)

Thompson Watershed, Moscow

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1									---	.42	.46	.38
2									---	.52	.39	.36
3									.51	.50	.47	.16
4									.51	.44	.49	.07
5									.51	.51	.38	.31
6									.42	.51	.46	.16
7									.34	.53	.50	.11
8									.30	.46	.46	.27
9									.25	.48	.47	.36
10									.27	.40	.47	.36
11									.41	.43	.46	.35
12									.19	---	.47	.35
13									.33	---	.46	.24
14									.07	---	.49	.31
15									.11	---	.45	.35
16									.22	.37	---	.16
17									.51	.48	.47	.19
18									.49	.49	.44	.06
19									.49	.46	.39	.22
20									.49	.48	.40	.13
21									.49	.44	.41	.15
22									.48	.32	.39	.05
23									.45	.47	.37	.20
24									.49	.34	.37	.30
25									.49	.13	.39	.31
26									.39	.30	.39	.30
27									.12	.35	.37	.29
28									.30	.18	.38	.28
29									.17	.48	.36	.27
30									.43	.47	.30	.22
31									---	.49	.33	---
TOTAL									10.23	11.45	12.64	7.27
AVG									0.37	0.42	0.42	0.24

DAILY WIND DISTANCE IN MILES (1969-1970)

Thompson Watershed, Moscow

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1											--	86
2											--	86
3											--	99
4											65	81
5											56	102
6											49	161
7											101	132
8											108	156
9											47	62
10											45	97
11											41	108
12											60	113
13											99	77
14											56	50
15											44	58
16											96*	84
17											65*	112*
18											65*	75*
19											65	75
20											49	38
21											45*	71
22											52*	--
23											52	--
24											47	--
25											58	--
26											59	--
27											49*	--
28											92*	--
29											92*	--
30											92*	--
31											91	--
AVG											65.7	91.6

*Total miles for this period was distributed uniformly over these days.

PAN EVAPORATION IN INCHES (1969-1970)

Thompson Watershed, Moscow 1/

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1										---	.32	.17
2										---	.17	.27
3										---	.22	.05
4										---	.38	.00
5										---	.31	.10
6										---	.32	.11
7										---	.28	.05
8										---	.30	.19
9										---	.25	.14
10										---	.26	.25
11										---	.14	.22
12										---	.13	.23
13										---	.29	.12
14										---	.28	.12
15										---	.31	.16
16										---	.37	.14
17										.32	.30	.17
18										.24	.27	.01
19										.37	.27	.12
20										.35	.30	.13
21										.30	.30	.06
22										.26	.34	---
23										.24	.42	---
24										.38	.28	---
25										.06	.36	---
26										.16	.30	---
27										.12	.23	---
28										.07	.38	---
29										.27	.25	---
30										.19	.30	---
31										.24	.33	---
TOTAL										3.57	8.96	2.81
AVG										0.24	0.29	0.13

1/ Evaporation was from the surface of a standard 4-foot diameter pan, but depths shown include any effect of storage and evaporation in the 16-inch well for the recorder float.

AVERAGE WATER TEMPERATURE IN
EVAPORATION PAN (1969-1970)

Thompson Watershed, Moscow 1/

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1										--	--	66
2										--	71	62
3										--	70	54
4										--	71	49
5										--	74	51
6										--	74	53
7										--	73	51
8										--	--	49
9										--	--	52
10										--	65	55
11										--	--	52
12										--	70	47
13										--	66	43
14										--	65	47
15										--	69	50
16										78	67	48
17										74	62	54
18										--	62	52
19										--	67	52
20										73	68	47
21										--	68	50
22										--	71	43
23										67	72	--
24										69	74	--
25										--	69	--
26										--	65	--
27										68	64	--
28										72	62	--
29										57	64	--
30										63	65	--
31										66	69	--
AVG										68.7	68.0	51.2

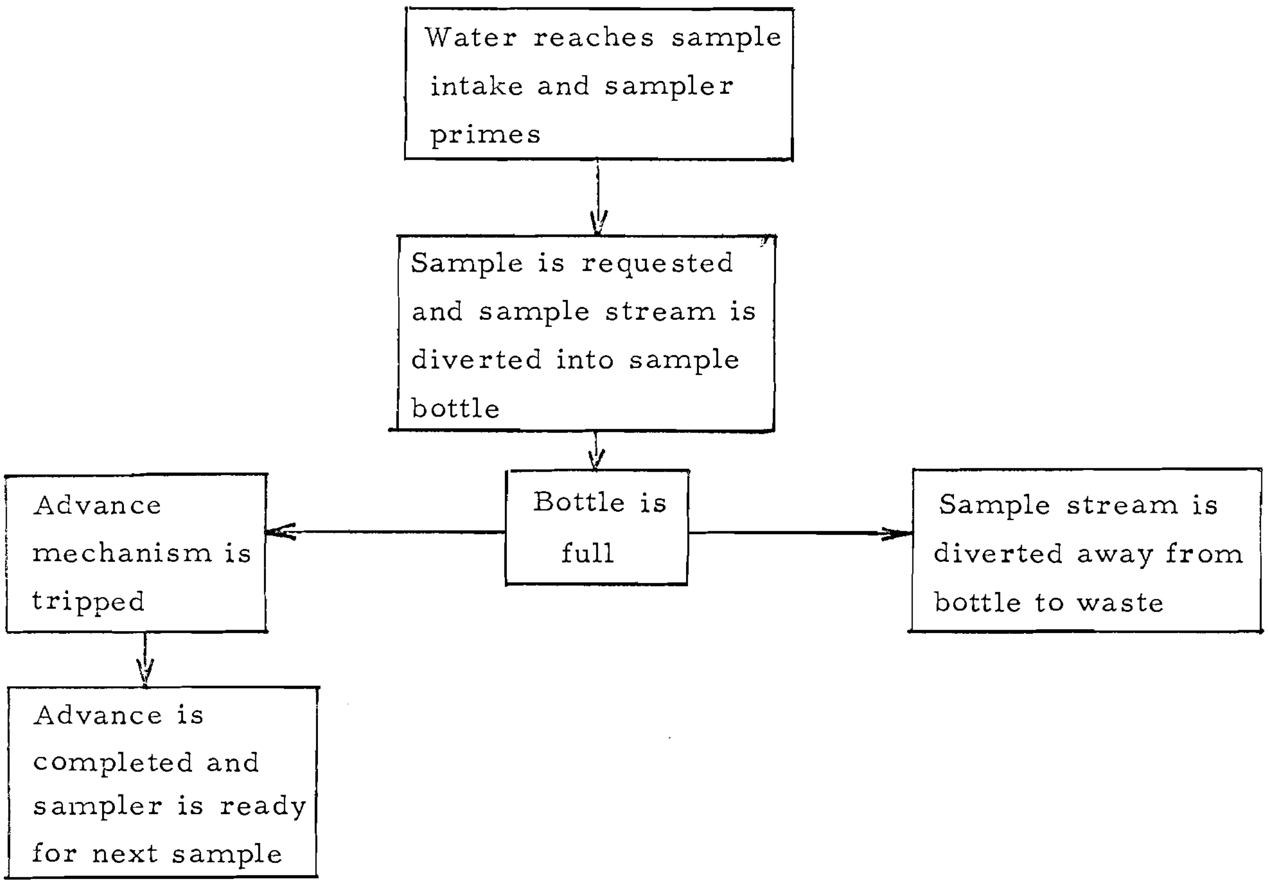
1/ Average is the average of the maximum and minimum temperatures.

Appendix 2

Sediment sampler report

Sample Design and Laboratory Testing

The basic steps which any sediment samples must follow are shown by the block diagram below. The water and sediment mixture must be carried to the sample bottle. Some means must be provided to divert the sample stream into the bottle while it fills and then remove the sample stream when the bottle is full. Another device is needed to sense when the bottle is full. Finally, some means must be provided for preparing the system for a new sample.



Block diagram of sampler operation

Because of its proven design, low cost, and ease of construction, the basic configuration of the Chickasha Sediment Sampler (Miller and others, 1969) was chosen as the starting point for design of a gravity feed sediment sampler.

Two modifications were required. The first is the addition of a device to operate the sample solenoid and the second is a device to sense when the bottle is full.

Since no timer is involved, the sample solenoid must be kept energized by some other means. A silicon-controlled rectifier (SCR) was chosen for this purpose. Once the signal is received by the SCR that a sample is desired, it will go into a state of conduction and remain so even if the initializing signal is removed. The SCR is shut off by breaking the line from the battery to the SCR. This is accomplished by using a SPDT switch which is incorporated in the scale which is used to sense when the bottle is full (Figure 2). About 20 seconds is required to go through the entire sample sequence. Since the sampler at the Thompson Watershed operates on a stage basis, it is not possible to regulate the length of the initializing pulse which is used to turn on the SCR. Therefore a blocking capacitor is installed in series with the SCR gate. This capacitor charges and blocks the current flow below the gate current for the SCR. Thus the SCR will not conduct until the capacitor is discharged.

No flushing of the system is necessary because the sample stream runs at all times that the water surface is above the inlet on the drop-box weir. Since the sampler is mounted below the weir outlet, there is always the possibility of water striking the sampler. Thus a cover should be used to both protect the samples from contamination and to protect the scale mechanism.

TESTING

The sampler was tested in the hydraulic laboratory using a large flume as a substitute for a weir. The sampler was set up to operate as in the field and, after initial adjusting, performed successfully through several cycles.

Unfortunately, no runoff events have occurred since the sampler was installed at the Thompson Watershed.

Further testing is now proceeding on a photoelectric sensor to take the place of the scale or of the SPDT switch on the scale. Several problems have been encountered, the most important of which is the sensing of very clear snowmelt water. Another alternative which will be tested in the laboratory is the use of a time delay relay in the place of the SCR. This would provide for a 20-second holding of the sample solenoid and may eliminate the need for the balance.

Some design details (see Figure 2):

1. SCR must be rated 24 volts, 4 amps or better.
2. R must be chosen to limit the SCR gate current to less than the maximum value for the particular SCR.
3. C is chosen so the RC time constant is 5 seconds or less.
4. The SPDT switches are any good quality, very light action, 2-ampere microswitch.
5. As the tray advances, the bottle must drop off the balance before the advance solenoid can release and stop the tray from moving.
6. Solenoids may be either linear or rotary. Linear solenoids were used in this design (Dormeyer B25-754-A-1) because of their availability. However, a rotary solenoid has a real advantage for the sample solenoid.

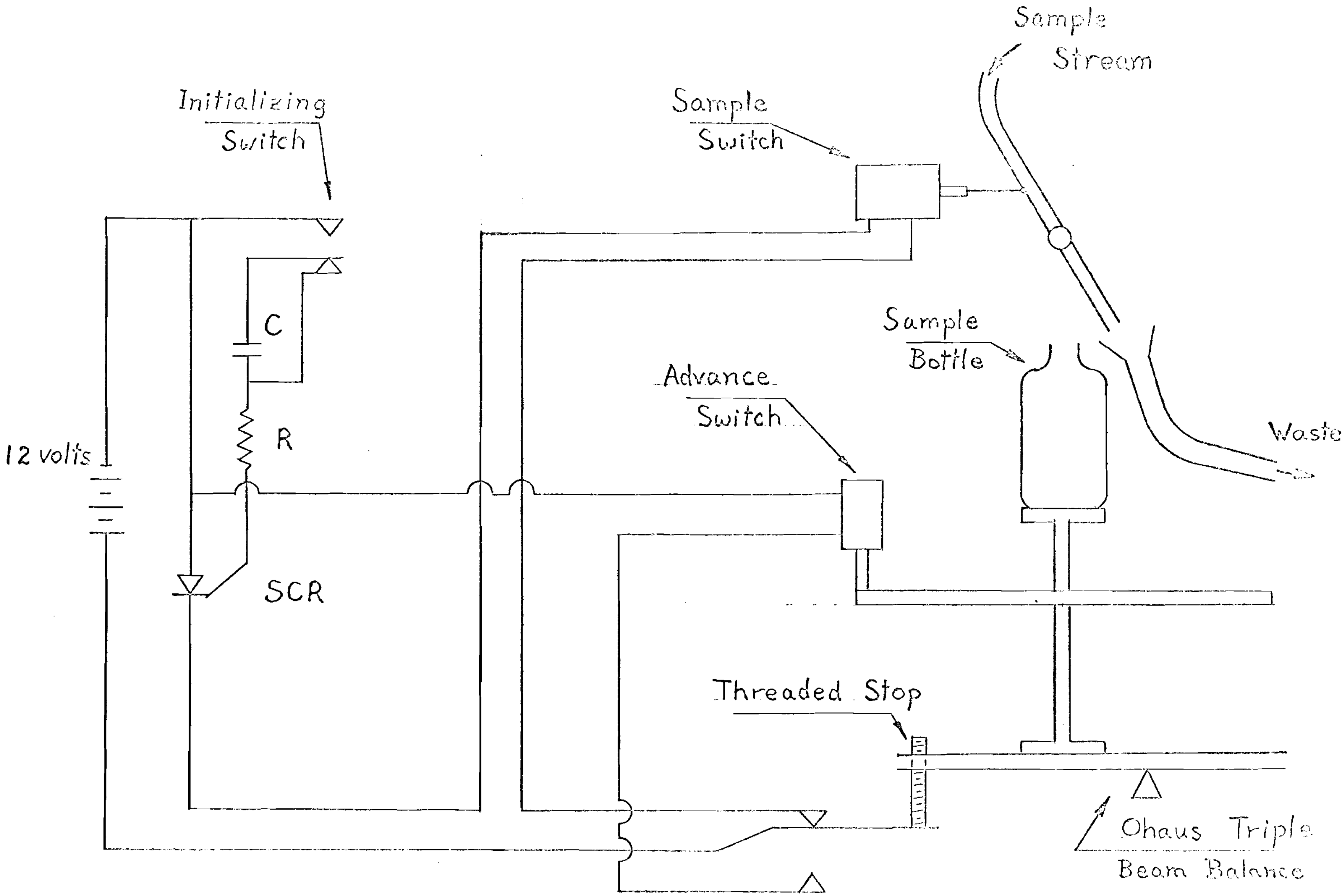
REFERENCES

Federal Inter-Agency Sedimentation Project, 1961. The Single-Stage Sampler for Suspended Sediment. Report No. 13. U. S. Government Printing Office, Washington, D. C.

Miller, Gary E., Paul B. Allen, Norman H. Welch, and Edd D. Rhodes. 1969. The Chickasha Sediment Sampler. USDA-ARS 41-150.

Molnau, Myron. 1969. Influence of Some Environmental Factors on CIPA Movement into Soils. Unpublished PhD dissertation, Iowa State University, Ames, Iowa.

Ritter, W. F., Myron Molnau, H. P. Johnson, and W. G. Lovely. 1970. Pesticides in Runoff and Sediment Go from Small Agricultural Watersheds. American Society of Agricultural Engineers, St. Joseph, Michigan.



Schematic of the sample sensing and switching mechanism.