August 1972 WRRI No. 002

PROJECT 13030 GLM

QUALITY AND QUANTITY OF RETURN FLOW AS INFLUENCED BY TRICKLE AND SURFACE IRRIGATION

ACCOMPLISHMENTS

During this first project year much time was spent on preparing the field plots and on installation of equipment for measuring water and salt flow. Progress was made according to the work schedule prepared with the project proposal. A copy of this work schedule is presented as Figure 1. The accomplishments for the various tasks outlined in this work schedule will be discussed below in the sequence they appear in Table 1. Data available so far, are included under each task description. Inasmuch as this project started July 1, 1971, too late for the 1971 cropping season, no data are available on the amount and quality of return flow for the 1971 cropping season.

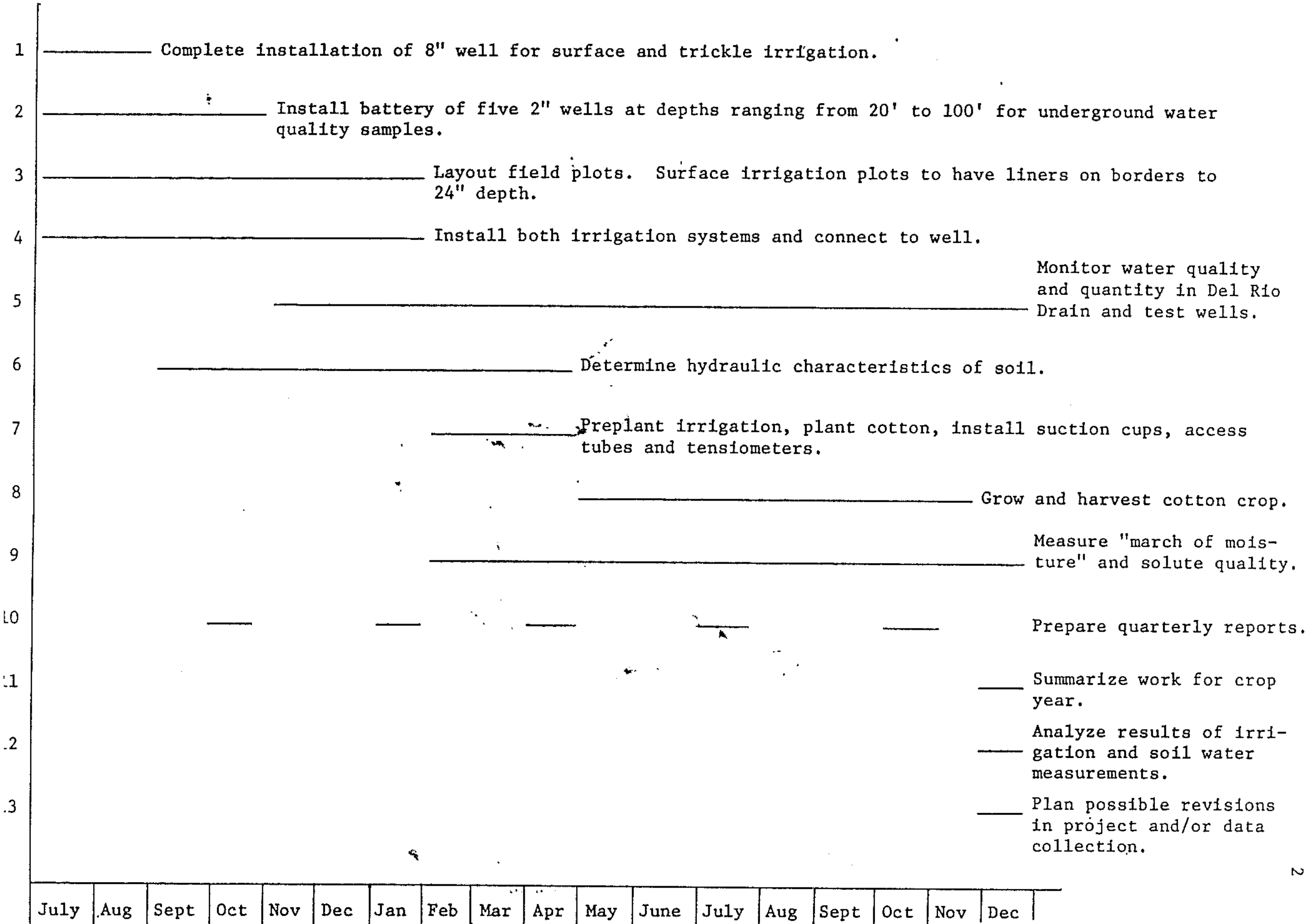


Figure 1. Task Description and Timetable for the First 18 Months of Work

1. Well Construction - Design - Performance

An eight-inch well was installed and gravel packed in a 12-inch hole to furnish all irrigation water for the project. The soil formation in the valley is "recent alluvium". The surface soil of approximately three feet is underlain by river sand from 3 to 54 feet. A coarse sand and gravel strata is located at depths of 54 to 84 feet. Drilling stopped at 84 feet. The water table was at 12 feet. The 8-inch casing has a Wesco keystone slotted screen extending from 54 to 84 feet. A water lubricated vertical turbine pump with a 5-inch outside diameter column was installed. The pump delivers 300 gpm at a dynamic head of 88 feet. The bowls were set at 55 feet. The motor driving the pump is a conventional vertical hollow shaft type, 10 hp, for 480 volts, 3 phase, 60 cycle current. Approximate speed is 3600 rpm. Figure 2 shows the construction of the well.

In drawdown tests run on the well the drawdown was approximately 7 feet at 350 gpm.

A typical analyses of the well water used for irrigation is shown in Table 1.

Table 1. Chemical constituents of well water

$EC \times 10^3$	pH	Ca	meq/1 Mg	Na	K	Cl	CO_3	HCO_3	SO_4
1.45	8.07	3.62	1.80	5.10	.16	2.76	.46	2.96	5.84

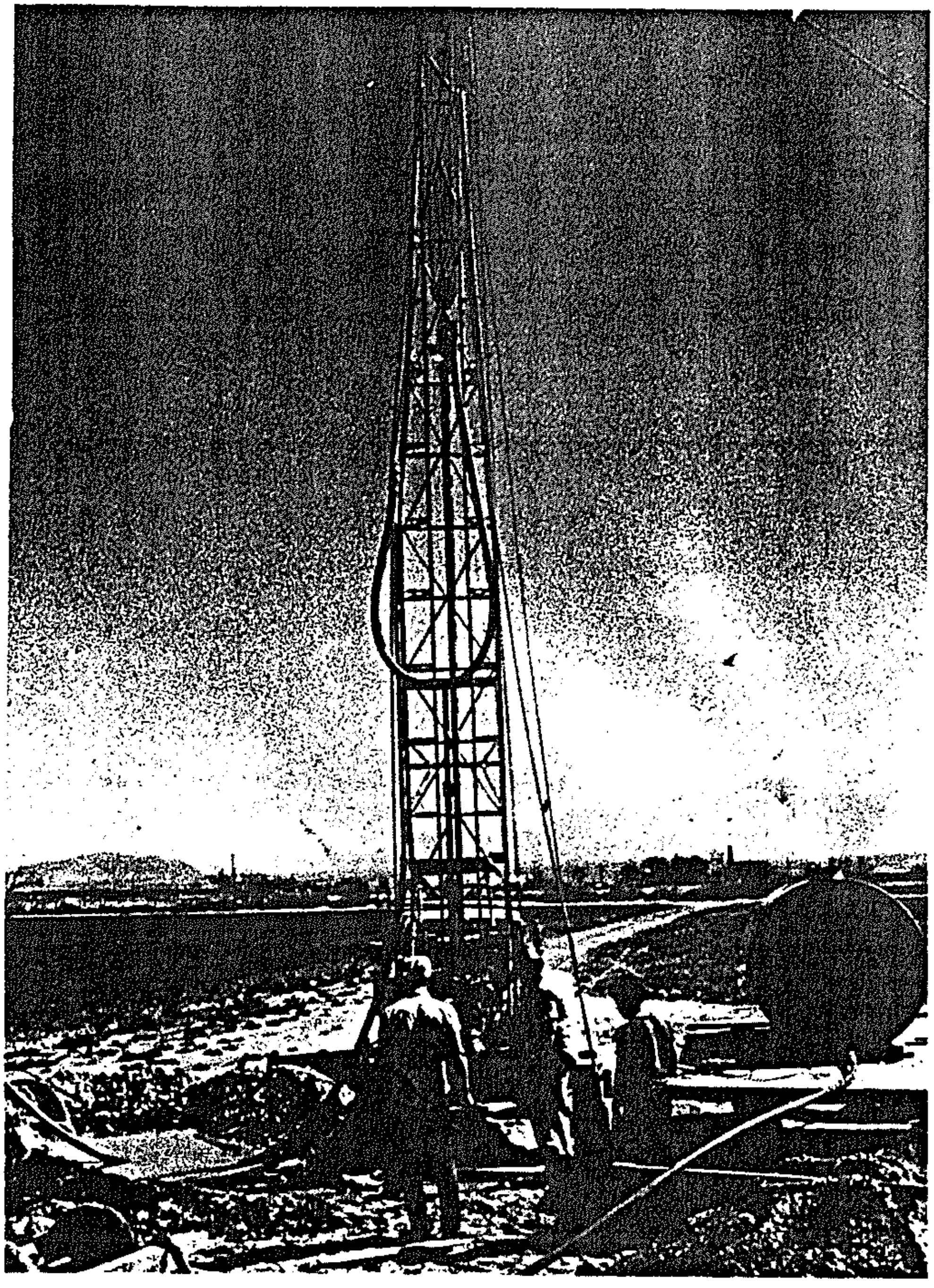


Figure 2. Construction of 8-inch well at the experimental site.

2. Observation Wells and Resulting Data

A battery of five observation wells was installed to monitor quality changes in the underlying aquifer and to monitor the water quality versus depth relationship within the shallow aquifer.

The wells range in depth from 19 feet to 75 feet. The casings are 1-1/4 inch schedule 200 PVC pipe and each casing has a two-foot section of slotted plastic well screen at the bottom. The five wells are connected to a pitcher pump through a manifold with valves to permit sampling from each of the five wells.

At each sampling sufficient volumes of water are pumped from each well to assure a representative sample from the sample depth specified.

The conductivity of samples by dates are shown by depth in Table 2.

Table 2. EC x 10^3 - Observation well samples

Well	Depth	4-20	5-26	6-2	6-17	6-26	6-30	7-7
1	75'	1.08	1.14	1.15	--	1.22	1.12	1.18
2	51'	1.35	1.58	1.52	1.68	1.78	1.76	1.80
3	36'	1.60	1.60	1.61	1.60	1.62	1.60	1.60
4	27'	1.70	1.48	1.43	1.44	1.42	1.40	1.42
5	19'	1.65	1.62	1.57	1.58	1.60	1.58	1.60

3. Field Plot Construction

Figure 3 shows the field plot layout at the experimental farm. Thirty plots, each 24 x 24 feet square, were constructed with plastic around each plot to a depth of 2.5 feet below the soil surface. Boards were installed

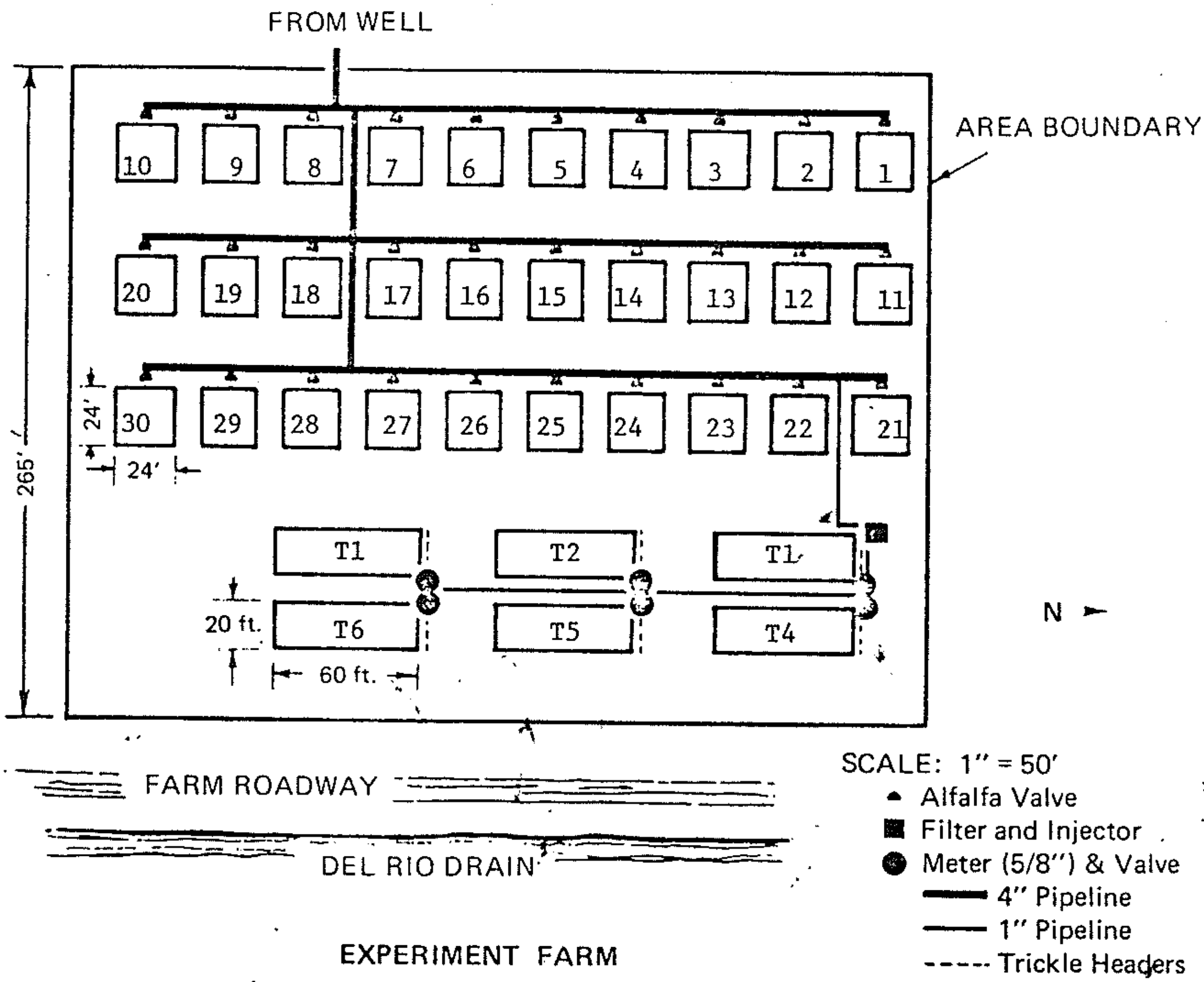


Figure 3. Field plot layout at the Plant Science Farm; the numbers inside the plot area designate plot numbers.

around each plot, extending 8 inches above, and 4 inches below the soil surface and wrapped in plastic. In all but a few plots, the plastic reached down into the sand. The plastic around the plots effectively prevents horizontal water movement out of the plot area, which otherwise may have taken place due to the low permeability of the 40-60 cm soil layer. Six plots, each 20 x 60 feet square, were prepared for trickle irrigation.

A large surplus trailer was obtained for the project. After some minor modifications the trailer now serves as field headquarters, as housing for the central vacuum system, as housing for the automatic control of the trickle irrigation system and as storage room.

4. Irrigation Systems

The surface system consists of a 4-inch main line and three 4-inch laterals which deliver water to an alfalfa valve located at each plot.

A hydrant connected to aluminum gated pipe (portable) completes the delivery to each plot. A rate of approximately 130 gpm per plot is used to minimize erosion. A 4-inch flow meter has been installed. All lines except the trickle headers and laterals are buried. Figure 4 shows the geometry of the irrigation systems installed. An overview of the installation of the main irrigation line is presented in Figure 5.

The trickle system installed was manufactured by the "Drip Eze" company and consists of row lateral, 60 feet long. The lateral is constructed from 3/8-inch P.E. pipe with emitters each 18 inches along the row. These laterals are connected to a one-inch PVC header at each plot. Individual positive displacement type meters have been installed at each plot. The system is operated at 15 psi which results in an emission rate of one gph per emitter, or 240 gph per plot. This is a rate equivalent to 1/3 inch per hour.

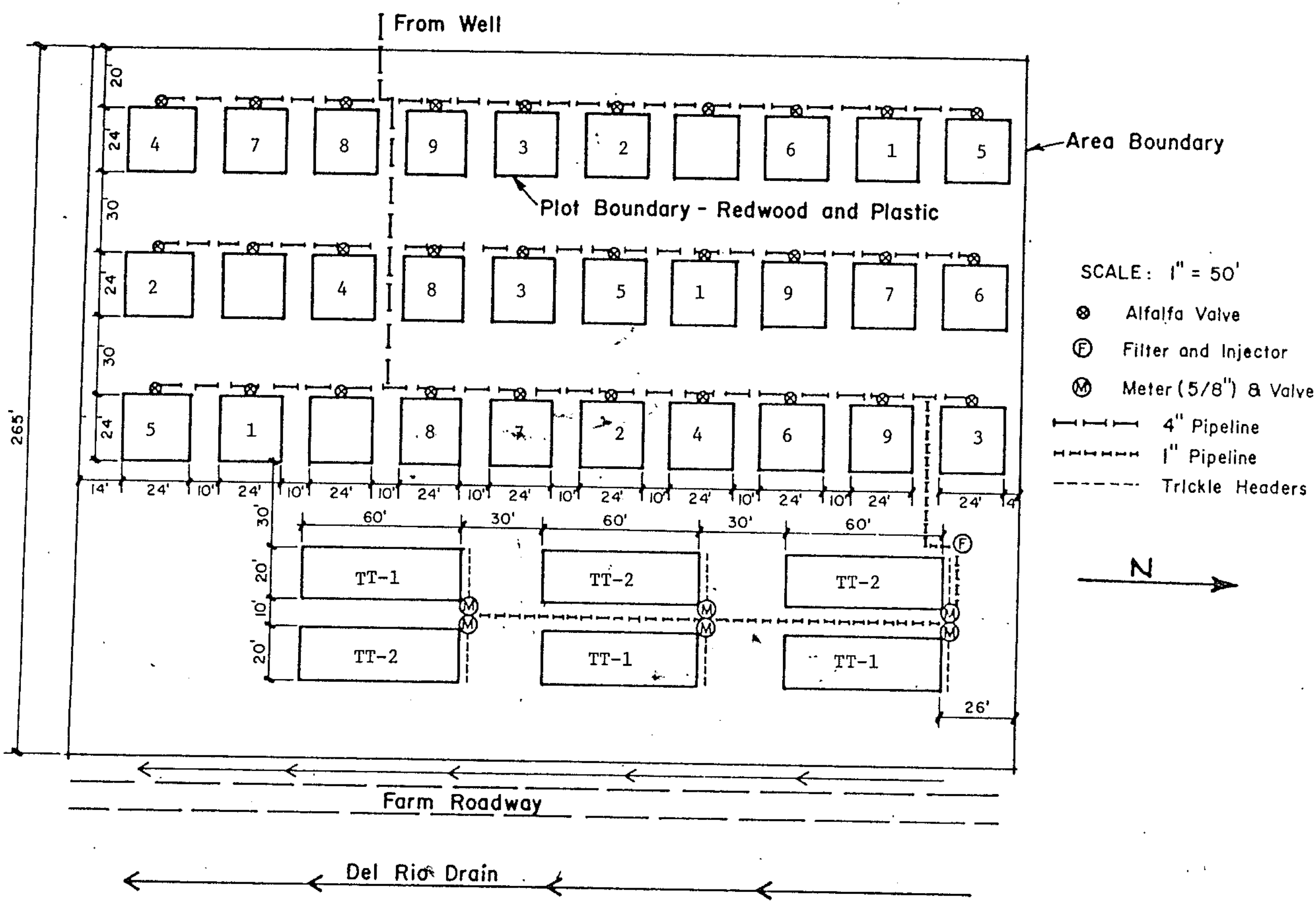


Figure 4. Geometry of plot area with irrigation systems. The numbers inside each plot designate the treatments.

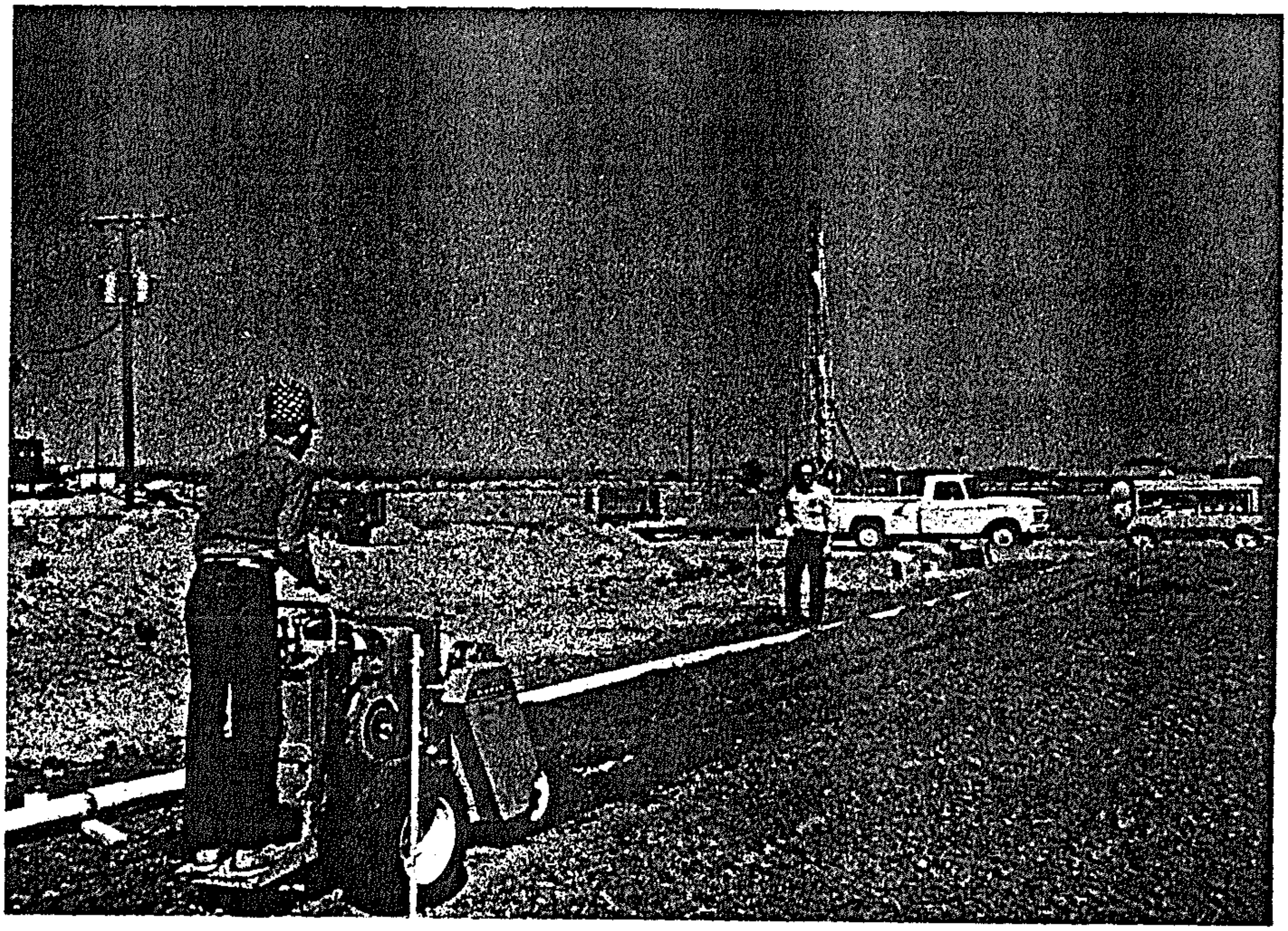


Figure 5. Installation of main irrigation pipeline system.

Flow is timed and controlled with hydraulic valves operated by a "Toro" hydraulic controller. The controller located in the instrument van is connected to the automatic valves by 1/8 inch I.D. tubing which has been buried.

5. Drain Installation and Data

Two sampling stations have been established along the Del Rio Drain. Station A is 2.8 miles upstream from the plot area and Station B is adjacent to the plot area. Water samples from the drain have been collected weekly at the two sites, since late December. The flow rates at the sampling stations are also being monitored. Staff gages were installed at culvert inlets near each sampling station. Bridges from which current meter readings are made were installed 30 feet upstream from the two culverts. Current meter readings are taken weekly, and the quantity of flow computed. A stage discharge curve for each site has resulted. Stevens water stage recorders have now been installed in stilling wells at each site and a continual record of stage maintained in order to determine the rate of flow at any time with the rating curves. A plot of flow versus time for both Site A and Site B is shown in Figure 6.

Project water was released from Elephant Butte Reservoir in early March, and irrigation with surface water commenced, causing an increase in drain flow from March through mid-April. At this time, the gates at Elephant Butte were closed and subsequent irrigation was from ground water resulting in a decline in drain flow from April through mid-June. In mid-June, an additional surface water allocation was made to valley farmers resulting in an increased drain flow from mid-June to date.

Figure 7 shows the EC of the drainage water samples versus time. In comparing Figures 6 and 7, it may be generally noted that periods of high

Figure 6. Del Rio Drain Flow

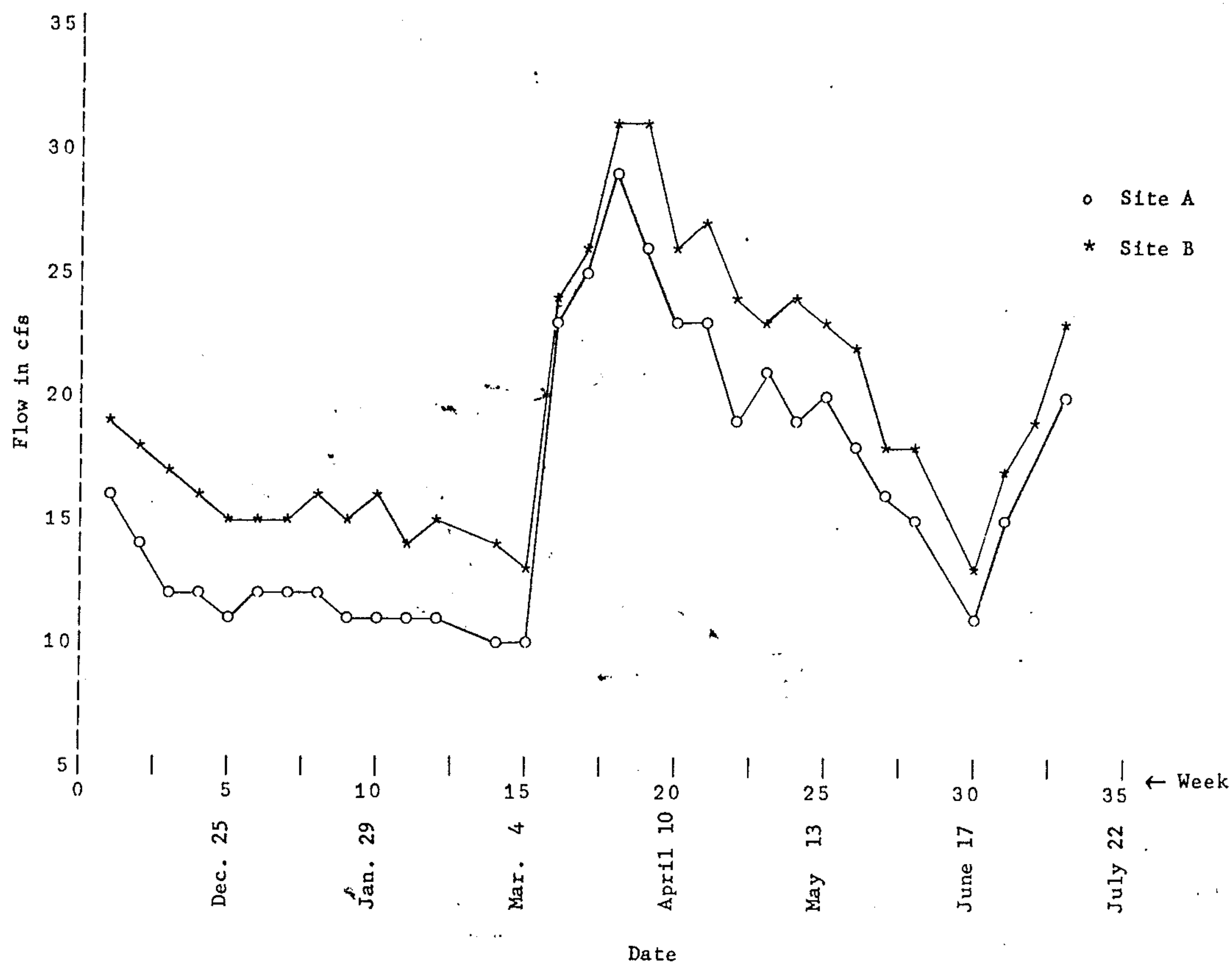
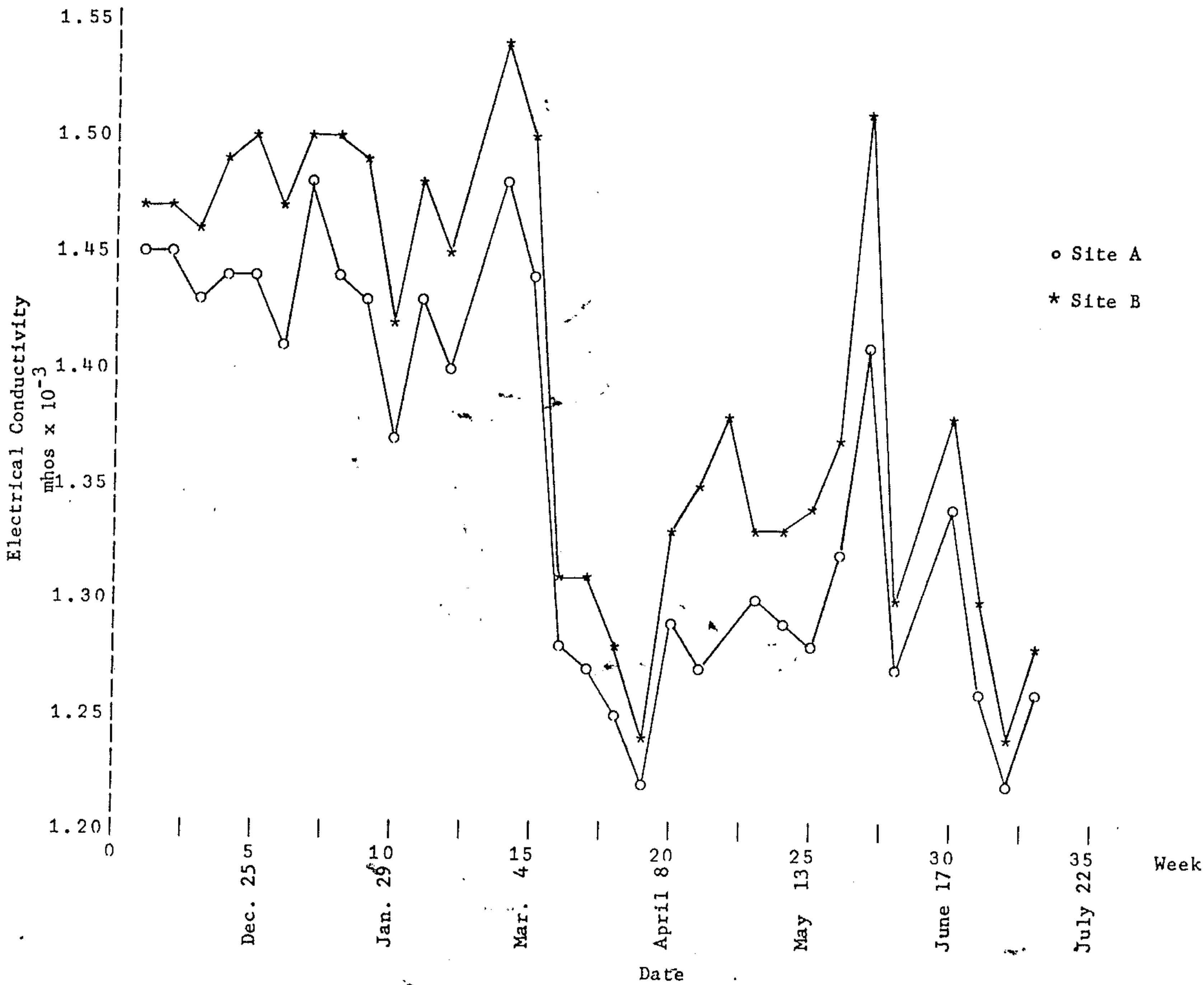


Figure 7. Del Rio Drain Flow



drain flow correspond with lower salt concentrations and periods of low drain flow correspond with higher salt concentrations.

A Typical Analysis of the drainage water appears in Table 3.

Table 3. Chemical constituents of drain water 6-24-72

Site	EC x 10^{-3}	pH	meq/l				meq/l			
			Ca	Mg	Na	K	Cl	CO_3	HCO_3	SO_4
A	1.26	7.70	5.73	1.69	5.84	.24	3.42	.58	3.68	5.77
B	1.30	7.77	5.95	1.73	6.03	.24	3.43	.48	3.64	6.25

6. Hydraulic Characteristics of the Soil

In order to determine the amount of leaching water from the plots the hydraulic conductivity of the soil below the root zone has to be known accurately. Three of the thirty 24 x 24 feet square plots have been set aside for this purpose. In the procedure for determining the conductivity of the subsoil the plots are ponded with water until no further change in soil-water pressure with depth within the profile is observed. The plots are covered with plastic and the changes in soil-water pressure with time, measured with three tensiometers at each depth, and the changes in soil water content with depth are recorded during the subsequent drainage period. From the changes in water content of the soil above a certain depth and the hydraulic gradient of the soil water at that depth, as measured with the tensiometers, the hydraulic conductivity of the soil at this depth can be calculated. The accuracy of this method depends to a large degree upon a reliable determination of the water content of the soil profile at various times after termination of the flooding. A detailed soil survey of the plot area has shown that the soil is extremely layered. It consists in general of 30 cm clay loam, on top of 30 cm clay, on top of medium fine sand. The sand contains many thin clay or loam lenses. Because the neutron meter has a relatively large sphere of influence (from 15 to 40 cm, depending on the water content of the soil) the water content in the top 25 cm of soil, and at the boundary between clay and sand cannot be determined accurately. A proposal has been made to purchase a two probe gamma ray density gauge. With such a gauge the water content is measured between two parallel tubes inserted vertically into the soil. In one of the tubes a gamma ray emitting source is lowered into the soil (Cesium 137), while a detector is lowered in the other tube. The intensity of radiation measured with the detector is a function of density of the material between the source and detector and thus of the water content of the soil. With such a system the water content can be determined in layers and also close to the soil surface.

Core samples have been taken around plot 3 (see Figure 3) for determination of the water release curve, the bulk density of the soil and the saturated hydraulic conductivity of the soil. Values of the saturated hydraulic conductivity of soil cores taken from pit #2 north of plot 3 are presented below.

Table 4. Values of saturated hydraulic conductivity (cm/day)

Depth(cm)	0-20	20-40	40-60	70-85	100-120	120-140	140-160
Conductivity	14.1	9.4	1.2	54.6	786.2	864.0	2272.3

The data in Table 4 clearly show the extreme layering of the soil at the experimental site.

7. Plant Cotton, Install Suction Cups and Tensiometers

After an 8-inch preirrigation, Acala 1517-70 cotton was planted on May 12 on the surface plots and May 15 on the trickle plots on 40-inch row spacing. The cotton was planted on level land, since it was not possible to form furrows or beds within the square field plots. Because the surface soil had dried out after the preirrigation, the square plots were irrigated by sprinkling after planting to ensure proper germination. Insufficient watering, and compaction of the surface layers resulted in relatively poor germination on some plots. The trickle plots were irrigated with the trickle lines next to each plant row. On June 29 all plots were fertilized with an amount equal to 80 lbs N and 40 lbs $P_2 O_5$ per acre, applied by side dressing as 30-15-0. This application was repeated on July 25, 1972.

Before planting, tensiometers, suction cups and neutron access tubes were installed close to the center of each plot. In plots 1-10 triplicate tensiometers were installed at 120 and 150 cm with three suction cups at 135 cm. In plots 11-20 the tensiometers and suction cups were installed at depths of 135, 165 and 150 cm respectively. In plots 21-30 and in the trickle plots the tensiometers and suction cups were placed at 150, 180 and 165 cm respectively. All suction cups were connected through an underground vacuum system to a central vacuum pump located in the instrument van. The samples from the suction cups are collected in bottles just outside the plot area. All tensiometers were connected through underground nylon tubing to mercury manometer placed in louvered instrument shelters outside the plots. Two neutron access tubes were installed near the center of each plot to a depth of 5-1/2 feet below the soil surface.

Figure 8 shows the set-up for one of the surface plots.

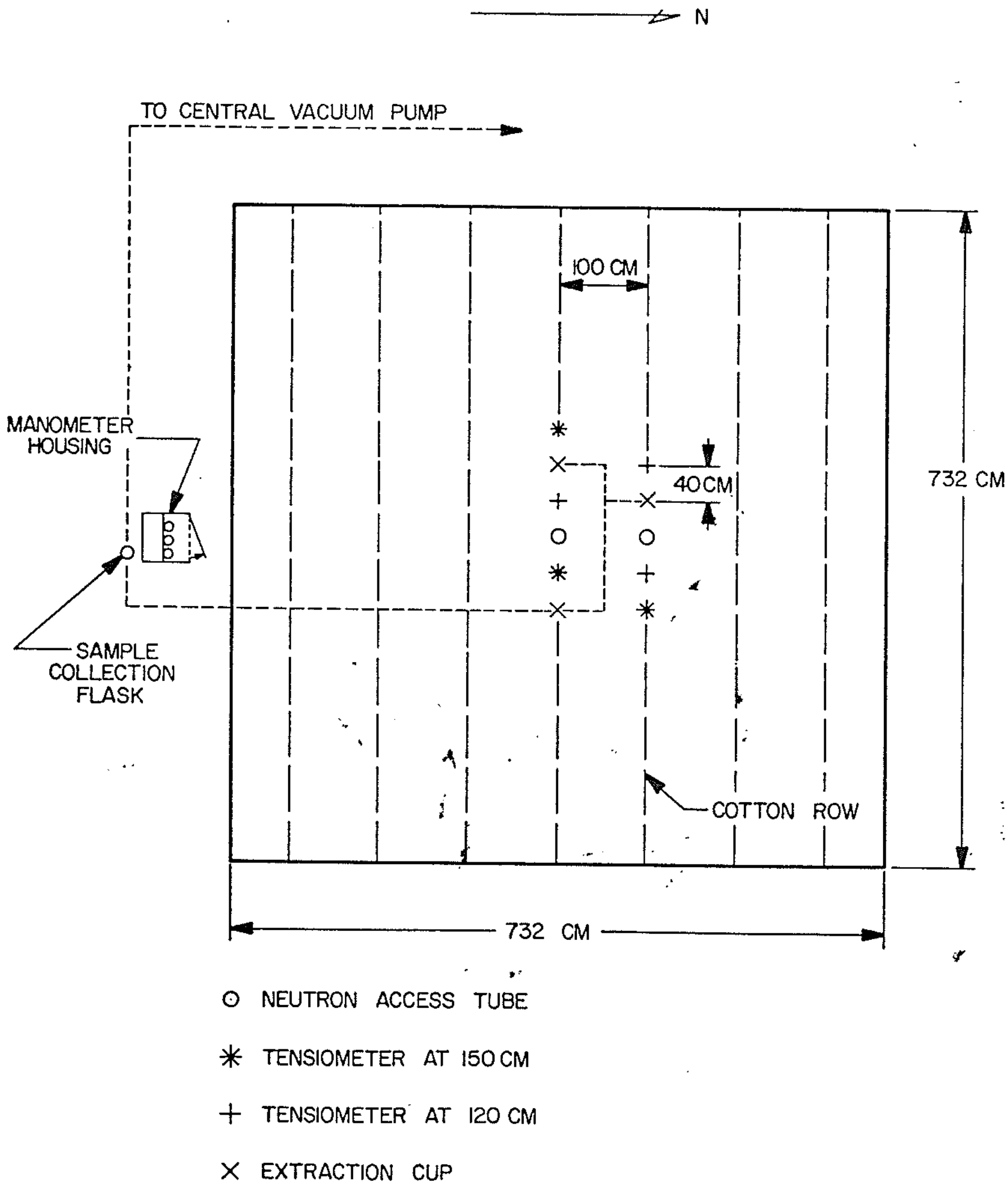


Figure 8. Experimental set-up of surface plot with tensiometers, suction cups and neutron access tubes.

8. Growing and Harvesting the Crop

The irrigation treatments as set up in the project proposal were block randomized over the plots. Three depletion levels are being investigated. It is common practice to use 50 percent depletion of total available moisture in designing irrigation systems. Farm practice varies considerably above and below this level and is fairly well represented in the range of treatments selected below:

L_1 = 25% depletion

L_2 = 50% depletion

L_3 = 75% depletion

In the project, all types of water loss during surface irrigation, except evaporation and deep percolation, have been eliminated. Neglecting evaporation from the water surface during irrigation, the water applied is equal to the water stored plus deep percolation.

Three field application efficiencies have been selected.

E_1 = 50%

E_2 = 75%

E_3 = 100%

The surface treatments then consist of combinations of frequency (based on depletion) and efficiency.

T_1	$L_1 \times E_1$
T_2	$L_2 \times E_1$
T_3	$L_3 \times E_1$
T_4	$L_1 \times E_2$
T_5	$L_2 \times E_2$
T_6	$L_3 \times E_2$

T_7	$L_1 \times E_3$
T_8	$L_2 \times E_3$
T_9	$L_3 \times E_3$

Each treatment was block randomized with three replications. Location of the block randomized plots is shown in Figure 4.

Frequency of irrigation originally was to be based on moisture changes within the root zone as determined by the neutron meter. As was agreed between Dr. Law and the principal investigators at a meeting at NMSU on June 14, the depletions are being monitored by a relationship to pan evaporation.

A standard weather bureau pan has been installed at the plot site. In using pan evaporation, the data are corrected with a season-dependent crop coefficient and adjusted for rainfall. The coefficients used are computed on methods outlined for modification of the Blaney Criddle method in Soil Conservation Service Technical Release 21.

Table 5 shows the accumulated amount of irrigation water applied to the various treatments as of July 17, 1972.

Table 5. Surface Application

Treatment	Total Water Applied (inches)	Water Applied Since Pre-Irrigation (inches)
1	19.49	11.49
2	16.95	8.95
3	20.93	12.93
4	16.94	8.94
5	15.27	7.27
6	18.03	10.03
7	15.78	7.78
8	14.48	6.48
9	16.64	8.64

Two treatments are replicated three times under trickle irrigation. The location of plots are shown in Figure 4.

Trickle treatment 1 (TT1) stipulates that tension at the 6-inch level be maintained at or below .2 atmosphere. Trickle treatment 2 (TT2) stipulates that tension at the 6-inch level be maintained at or below .6 atmosphere. Originally .4 and .6 were to be used but recent work on trickle at New Mexico State University indicates no significant differences in water use or yield between .4 and .6 atmosphere.

Table 6. Trickle Application

Treatment	Total Water Applied (inches)	Water Applied Since Pre-Irrigation
TT1	15.95	7.95
TT2	13.02	5.02

9. Measure "March of Moisture and Solute Quality"

Before irrigation of the plots, soil samples were taken at 20 cm depth intervals just outside each plot area. The samples were taken to the laboratory for determining the salt concentration of the saturation extracts. Table 5 shows the electrical conductivity of the saturation extract for the second row of plots (e.g. plots 11-18).

Table 7. Electrical conductivity (mmhos) of saturation extracts from plots 11-18.

	Soil Depth(cm)			
Plot No.	0-20	20-40	40-60	60-80
11	3.11	5.43	6.20	6.45
12	3.25	4.37	5.98	2.78
13	3.17	4.37	6.93	--
14	3.10	5.21	5.97	5.23
15	1.90	2.48	4.32	4.06
16	2.15	2.71	4.50	5.00
17	2.00	--	4.65	5.15
18	3.35	5.51	6.30	4.52
Average	2.75	4.29	5.60	4.74

The data in Table 7 show considerable variation over the plot area, and within the soil profile. No data are available as yet on the soil solution extracted through the suction cups.

Task Description 1972-1973

In Figure 9 the task description and time table for the second year of study is presented. Inasmuch as the final program for the second year will depend to some degree on the results of the first year, the program in Figure 7 must be considered tentative. Possible revisions will be made only after all the data of the first year have been analyzed and discussed.

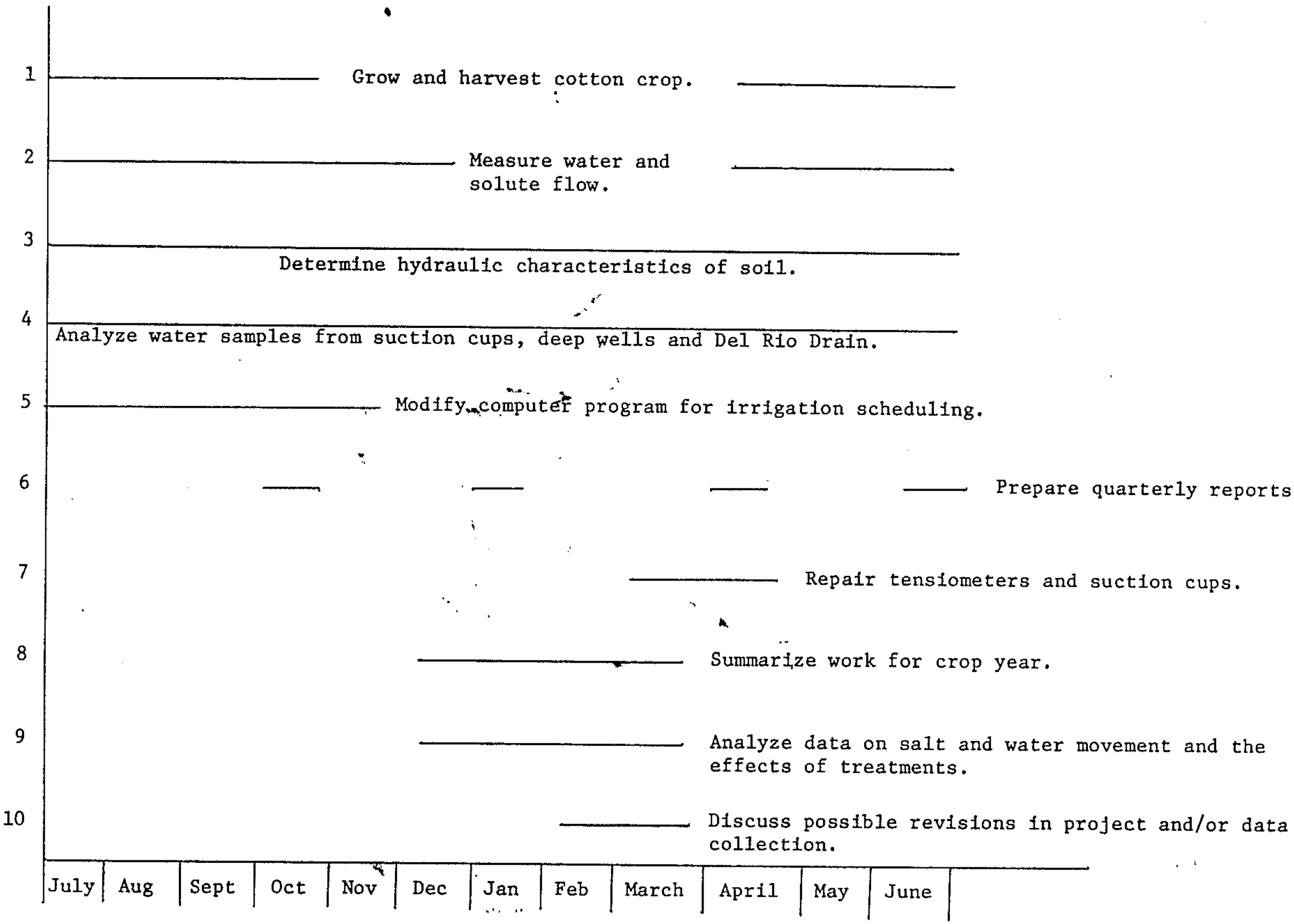


Figure 9. Task description and time table for second year of study.