RESEARCH TECHNICAL COMPLETION REPORT
PROJECT B-018-IDA

WATER for IDAHO

# Systems Analysis of Irrigation Water Management in Eastern Idaho

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Research Associate – Jos de Sonneville

Water Resources Research Institute
University of Idaho
Moscow, Idaho

October, 1973

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# SYSTEMS ANALYSIS OF IRRIGATION WATER MANAGEMENT IN EASTERN IDAHO

by

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Water Resources Research Institute
University of Idaho
Moscow, Idaho

Dr. John S. Gladwell, Director

## FOREWORD

The Water Resources Research Institute has provided the administrative coordination for this study and organized the interdisciplinary team that conducted the investigation. It is the Institute's policy to make available the results of significant water related research conducted in Idaho's universities and colleges. The Institute neither endorses nor rejects the findings of the authors. It does recommend careful consideration of the accumulated facts by those who are assuredly going to continue to investigate this important field.

## ABSTRACT

A water management study on a 96,000 acre irrigated tract in eastern Idaho was performed to develop techniques for regional water management studies and investigate alternatives for alleviating a high water table problem in the area. A complete water budget including irrigation diversions, system losses and wastes and crop consumptive use was determined. On farm water management practices, crop and property damage was determined. A finite difference digital aquifer model was developed to evaluate the response of the aquifer to changes in water management. The model which accommodates any type of aquifer boundary includes an automated calibration routine to adjust aquifer parameters to fit historical water table elevations. This routine is especially useful on aquifers with limited hydrogeological data. Results indicate that canal seepage and above average irrigation application rates are the main causes of the rise of up to 40 feet in water tables during the irrigation season. Alleviation of the problem could be achieved with a 20% or greater reduction in irrigation diversions or by lining of selected reaches of canals.

# ACKNOWLEDGMENT

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The advice and constructive criticism of the following individuals who reviewed the manuscript is greatly appreciated: C. Rice, Computer Analyst; J. Busch, Agricultural Engineering; and D. Ralston, Geology (all of the University of Idaho).

TABLE OF CONTENTS

Table of Contents (Cont.)

CHAPTER | PAGE

LIST OF TABLES

## LIST OF FIGURES

List of Figures (Cont. )

# INTRODUCTION

High water table problems occur annually during the irrigation season on the alluvial fan of the Snake River near the cities of Rigby and Ririe, Idaho.

Problems such as water in basements and potato cellars or flooded fields and corrals are prevalent. The cost to residents and businesses due to the high water table is estimated to be in excess of $24,000 annually.

Concern for the high water table problems experienced in the area resulted in the formation within Jefferson County of a sub-water committee to investigate possible causes and solutions to the problem. This research study on water use was begun in the Rigby-Ririe area of the upper Snake River Basin in May, 1970. The sub-water committee and the County Commissioners of Jefferson County requested the study and were very cooperative in formulating procedures for data collection and in securing field data. Meetings were held with the Jefferson County Commissioners and the Great Feeder Canal Board under whose jurisdiction a majority of the irrigation water is delivered to the area. Good cooperation has been received from the local farmers in the area and from the government agencies involved.

# OBJECTIVES

The problem of high groundwater tables and drainage that exists in the Rigby-Ririe area is typical of other areas in the State of Idaho. Because of the high rates of irrigation diversions to this area and the dense network of irrigation canals, this project afforded an excellent opportunity to study various aspects of regional water management in irrigation distribution systems.

Therefore, the objectives of this study were:

1) To develop techniques and procedures for analyzing regional water management problems; and
2) To evaluate the effectiveness of alternative water management programs on water table control.

It was evident early in the study that a general simulation model was required to effectively evaluate the response of the groundwater system to time and spatially variant inputs. Therefore the modeling effort was directed toward the following objectives:

1) To develop a suitable mathematical model such that theoretical solutions can be obtained in the form of flow patterns for a general two dimensional non-homogeneous groundwater basin with any groundwater table configuration.

2) To develop a calibration routine, used conjunctively with the model, that generates and changes parameter values which are directly related to the frequently unknown geological properties of the area so that it is possible to simulate historical seasonal water table changes of any year on record.

3) To investigate, using the calibrated model, the effects of alternate management solutions on the configuration of the water table in order to arrive at those management solutions that in effect will alleviate the water table problems as they occur in the Snake River Fan in eastern Idaho.

# STUDY AREA

The water management study area as shown in Figure 1 is located in Jefferson and Bonneville Counties in Townships 3, 4 and 5 N and Ranges 37 through 40 E of the Boise Meridian. The area selected for study comprises approximately 100,500 acres. The City of Rigby is located approximately in the center of the study area. This area is an old alluvial fan of the Snake River and is served by an irrigation system developed in the late 1800's by private and cooperative groups. The Great Feeder Canal which is an old channel of the Snake River runs east and west through the area and delivers water to some 20 smaller canals, each one operated by a separate and independent canal company or irrigation district. The material from which the irrigation canals are excavated is generally rocky and permeable.

## Climate

The Rigby-Ririe area of Jefferson County lies in the climatological area known as the Upper Snake River Plains with moderately warm summers and severe winters. Temperatures average about 68° F. in July and 17° F. in January. The growing season averages 123 days in duration and precipitation averages 8.7 inches.

## Soils

Agricultural soils of the Snake River Fan are dominated by medium texture soils as found on fan and stream bottom lands. Approximate

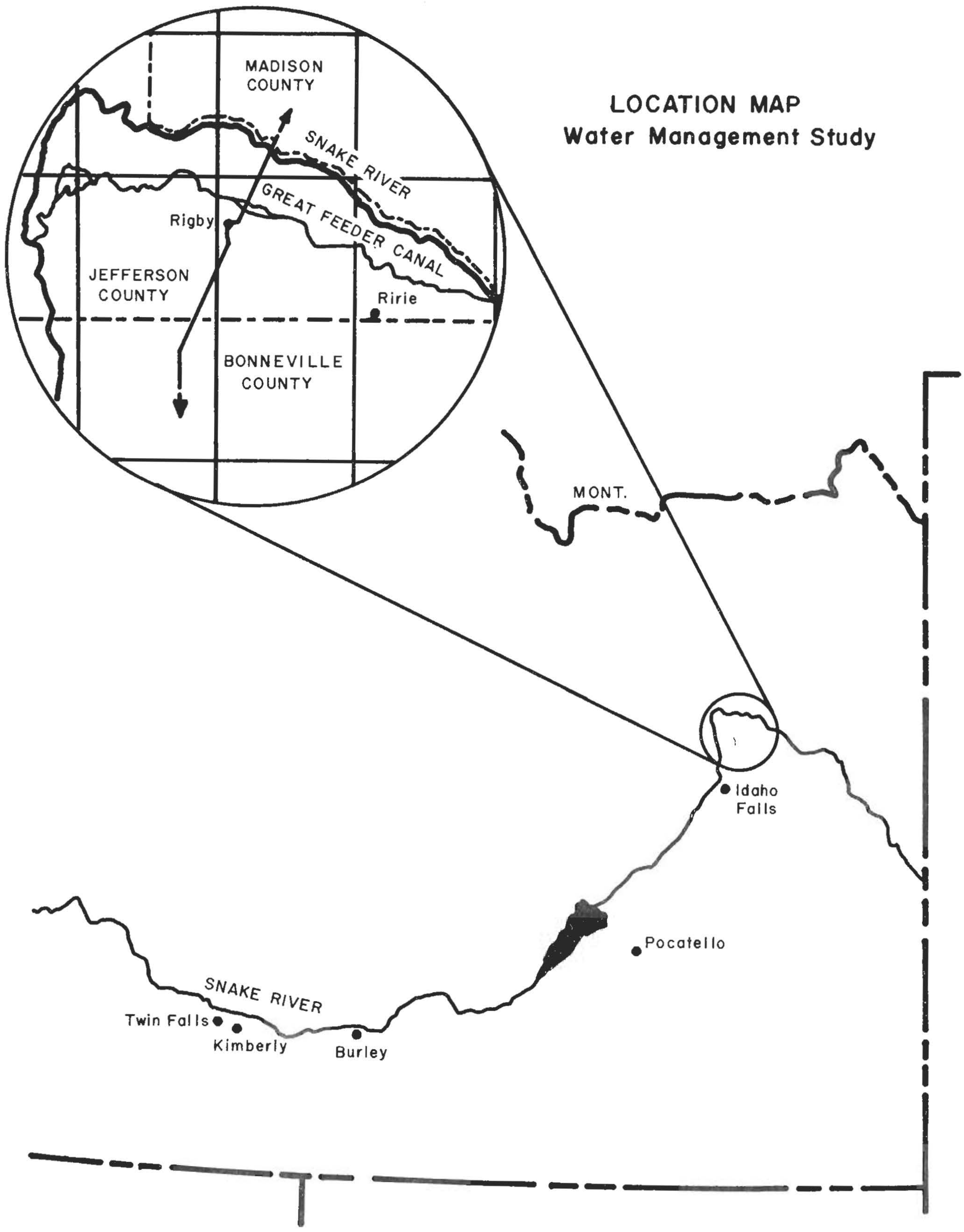



Figure 1. Location of the Study Area.

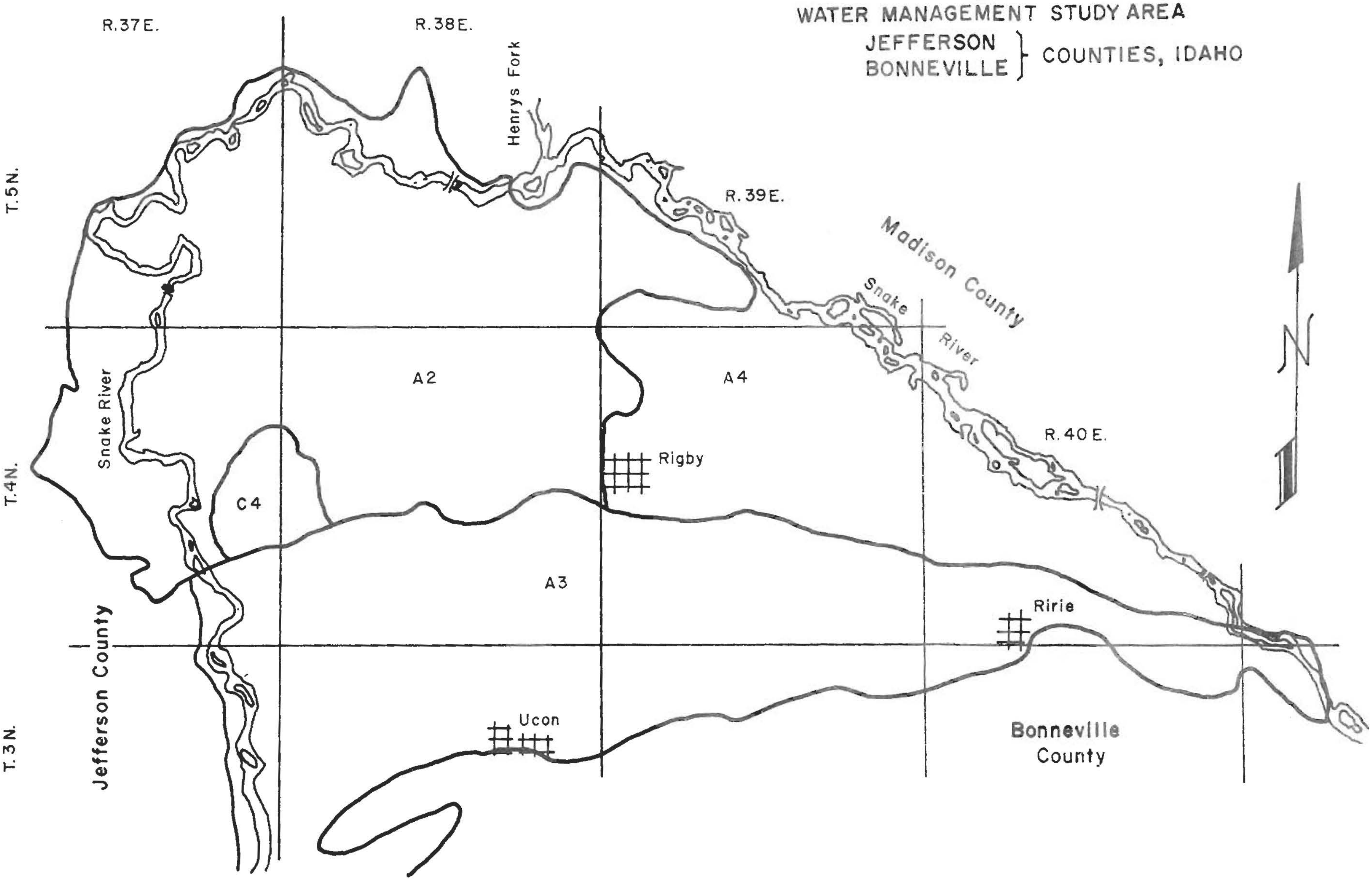



Figure 2. Approximate Locations of the Soil Associations in the Study Area.

locations of the soil association in the study area are shown in Figure 2. The A2 association comprises the better farm land and consists of silt and clay loams of 40-60 inch depth underlain by sand and gravel. This soil is moderately drained. The A3 association consists of the Bock and Bannock loam series of 10-60 inch depth over sand and gravel. These are well drained and contain up to 50% gravel in some areas.

The A4 association consists primarily of the Blackfoot-silt loam of 10-60 inch depth and a very shallow depth of 5-20 inch at some places. The soil group O4 overlies the Lewisville Knolls and supports range and wildlife.

All A type soils are mainly Class II or III capability for irrigated agriculture.

Crops

A crop survey conducted for this project indicates a distribution as follows:

| | |
|---|---|
| Mixed Grains | 31.1% |
| Alfalfa Hay | 38.8% |
| Irrigated Pasture | 20.6% |
| Potatoes | 8.1% |
| Corn | 0.4% |
| Sugar Beets | 1.0% |

Irrigation Practices

Border irrigation is used extensively on grains, alfalfa and pasture. Large stream sizes are prevalent with turnouts from the canals regulated in many cases by individual farmers. A water management survey was made in 1971 in which 70 farms were selected at random from the study area and personal interviews made with operators. Data on water use, irrigation practices, crops, field and farm size, fertilizer use and other farm operations were obtained. The area surveyed included 5, 454 acres on 70 farms.

The average farm size of those interviewed was 87 acres; however, no small (5-10 acre) farms were selected for interview. Estimates by University Cooperative Extension personnel indicate the average farm size including the small acreages may be near 40 or 50 acres. The average field size for the 487 fields on which data were collected was 11 acres with an average irrigation run length of 57 rods (940 ft. ). Full-time farmers comprised 62% of those interviewed while only 31% hire extra help. Stock management is an important part of the operation on 64% of the farms. Border irrigation is used on 88% of the fields and furrow irrigation on 11% of the fields.

Sixty-seven percent of the farms rotate the water supply with one other individual with average discharge available at the farm of 6. 2 cfs. Ninety percent of those responding indicated that water was not ponded on their fields or on nearby fields, yet 74% indicated that all of the applied irrigation water was retained on their fields with no runoff to drains or adjacent lands. These results corroborate field surveys which show a lack of natural surface drainage because of land leveling. Twenty-two percent of those responding indicated land damage had occurred due to high water table problems in the area.

Field evaluations of irrigation practices were conducted on both border and furrow systems. The furrow systems were all on potato fields while the border systems evaluated were cropped to alfalfa, grain and permanent pasture. Furrow irrigation of potatoes was found to be about 50% efficient if the wheel compacted row was used. Irrigation of the non-compacted row resulted in larger amounts of water being applied. Border irrigation data show that an average of about 15 inches per acre is being applied per irrigation where the irrigation requirement is only 4 to 5 inches.

Most of the low irrigation efficiencies found in this study result from run lengths too long for the high intake soils found in this area. Some also result from use of longer sets at night, varying lengths of run, poor leveling, etc.. Although, crop yields do not appear to be greatly reduced by the overirrigation, the excess application contributes to the high water table problem. The long runs are used because they are more efficient to farm and because trained labor for irrigating is difficult to obtain.

All of the irrigated lands in the study area are served from the Snake River with water rights dating as early as June, 1880. The majority of the area is served by irrigation canals diverting from the Great Feeder Canal which serves as a bypass for the Snake River main stream and generally runs continually. Management of deliveries to the smaller independent canals is the responsibility of a cooperative group called the Great Feeder Board.

Canal diversions to the area are recorded in the reports of the watermaster for Water District 1 (formerly District 36) of the State of Idaho commencing in 1919 through the present. Diversion records are maintained for the period of May 1st to September 30, although on many canals diversions continue into November but are not recorded on District 1 records.

# DATA COLLECTION

## Geology

Available well logs from the Idaho Department of Water Administration and local residents indicate that the gravel aquifer is extensive over the fan. However, very few of the domestic wells for which logs are available are greater than 100 feet deep so that the depth of gravels is not discernible over the entire fan.

One exploratory well, one and one-half miles northwest of Rigby is 1008 feet deep and indicates a 300 foot depth of gravel underlain by 170 feet of clay above basalt. Basalt is encountered at shallow depths south of Ririe and fingers of basalt extend eastward from the Lewisville Knolls on the western edge of the area into the gravels.

Water balance computations together with some evidence of the existence of interspersing clay layers indicate that an important percentage of the total water diversions leaves the area via leakage to the regional groundwater table of the Snake River Plain (6). The location and the magnitude of this leakage is unknown. From the available geological information only an estimate can be made of the values of the geohydrological parameters such as hydraulic conductivity, storage coefficient, impedance and head difference of a leaky aquifer system. A resistivity study was made in 1971 to assist in estimating the depth of gravel and approximate locations of clay lenses.

## Groundwater Table Elevations

A network of some 40 wells in the area was used to monitor changes in the groundwater table throughout the study. Figure 3 shows the locations of wells and well points measured in the network. Water table elevation contours were interpreted from these well recordings at three selected times in 1972-1973 for use in calibration of the simulation model. Figure 4 shows the historical water table contours for August 30, 1972.

In the vicinity of Rigby the water table rises as much as 40 feet from the beginning of irrigation in May to August. Maximum groundwater table elevations occur in August and associated problems are prevalent during August and September. Figure 5 shows the depth to the water table on August 30, 1972, as computed from the groundwater contours. The area north and west of Rigby as indicated in the figure had depths of water of five feet or less during July, August and September of 1972. The area around the City of Ririe is a local groundwater mound with depth to water of 10 feet and less.

## Surface Water Diversions

Irrigation diversions for the major canals in the study area for the May 1 - September 30 period are recorded in the reports of Water District 1.

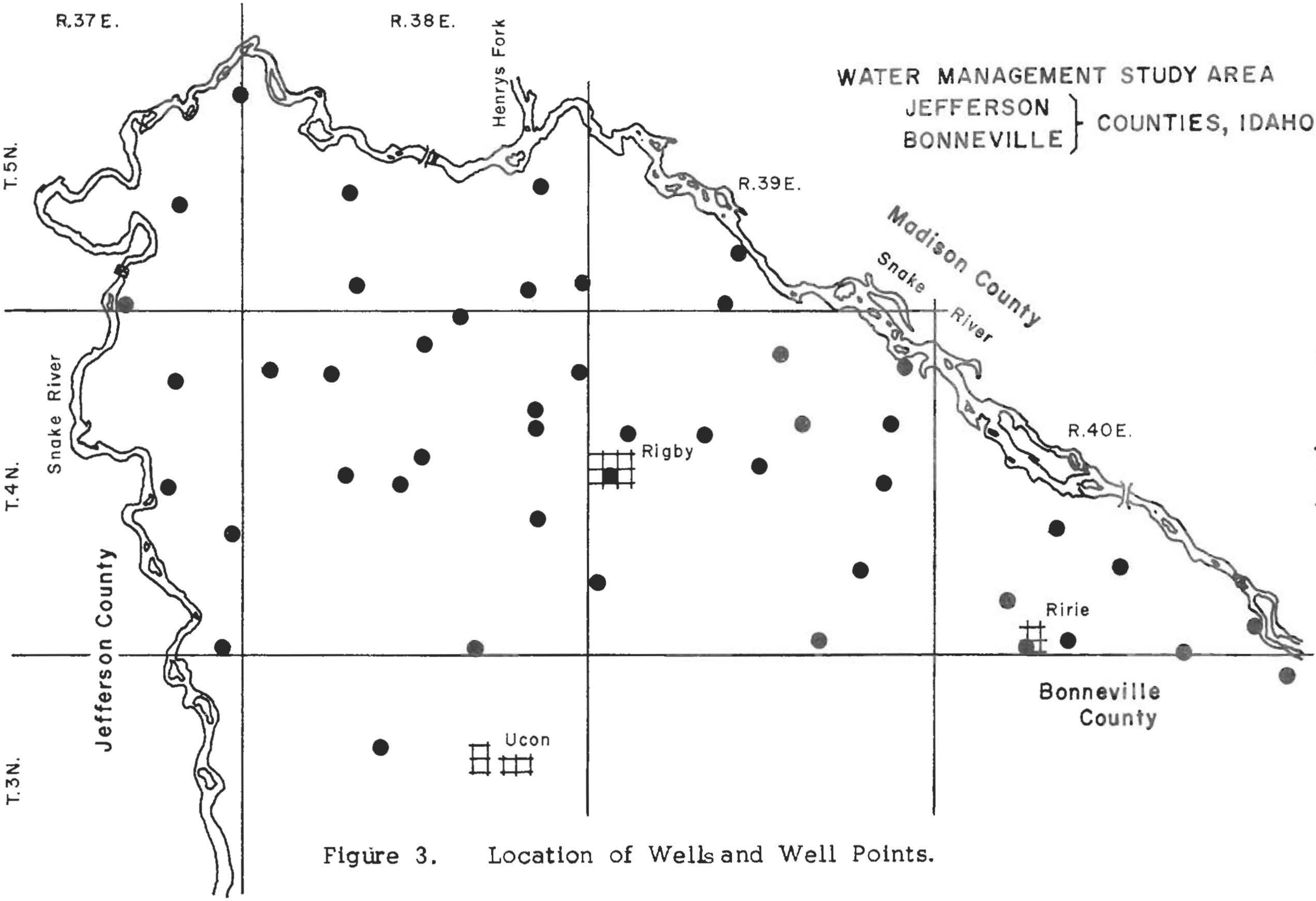



Figure 3. Location of Wells and Well Points.

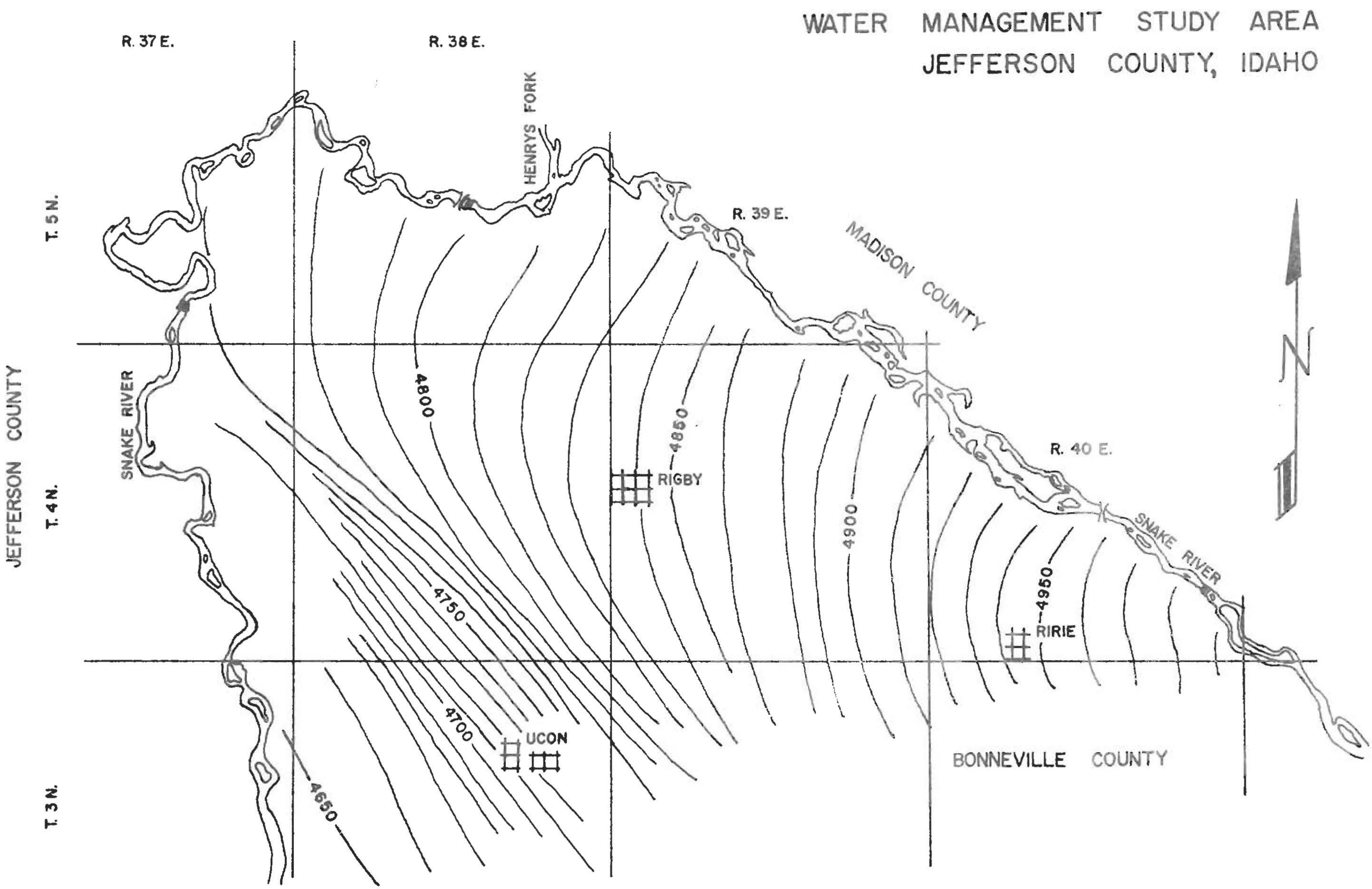



Figure 4. Groundwater Levels, August 30, 1972

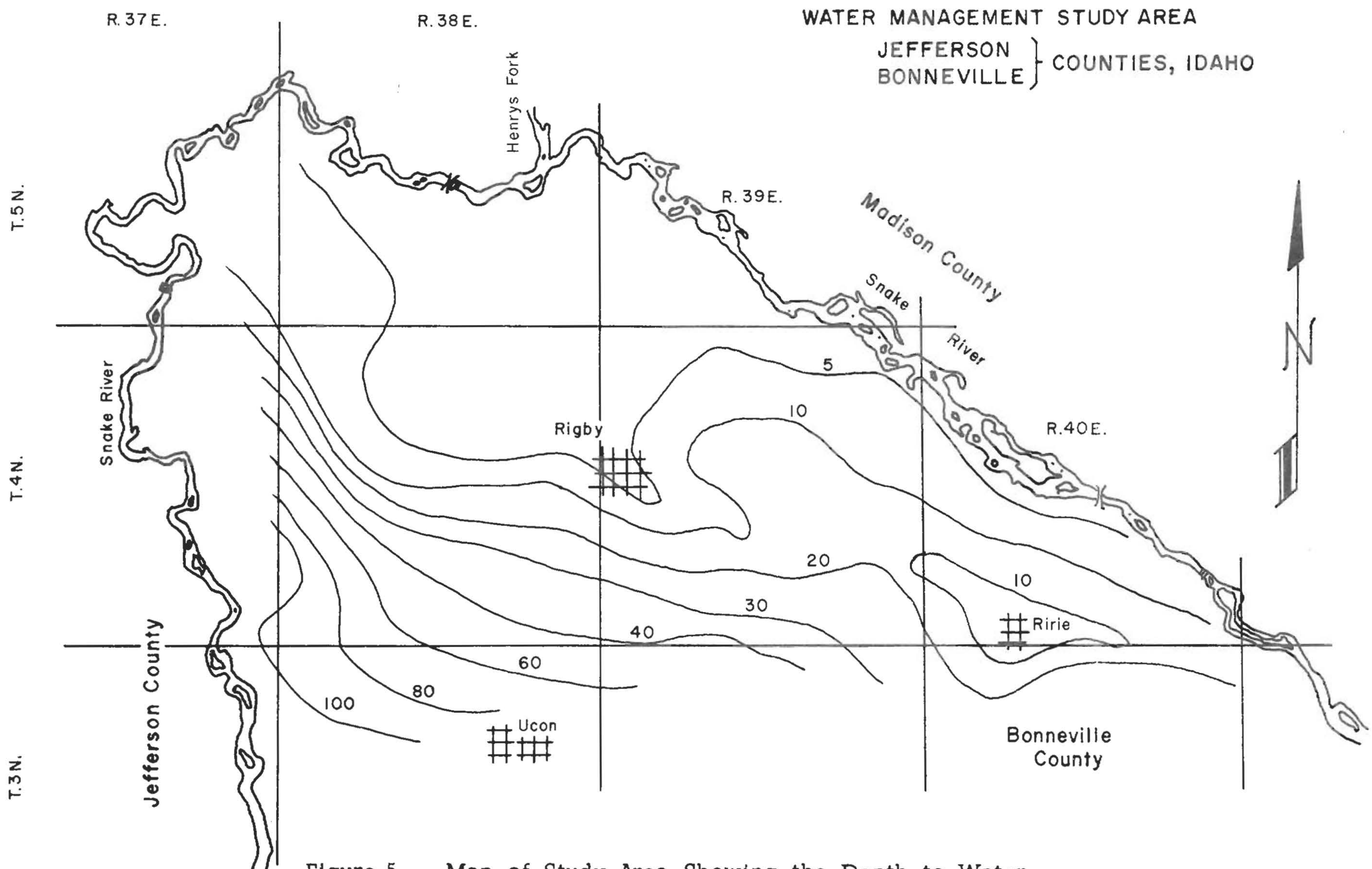



Figure 5. Map of Study Area Showing the Depth to Water Table August 30, 1972 in Feet.

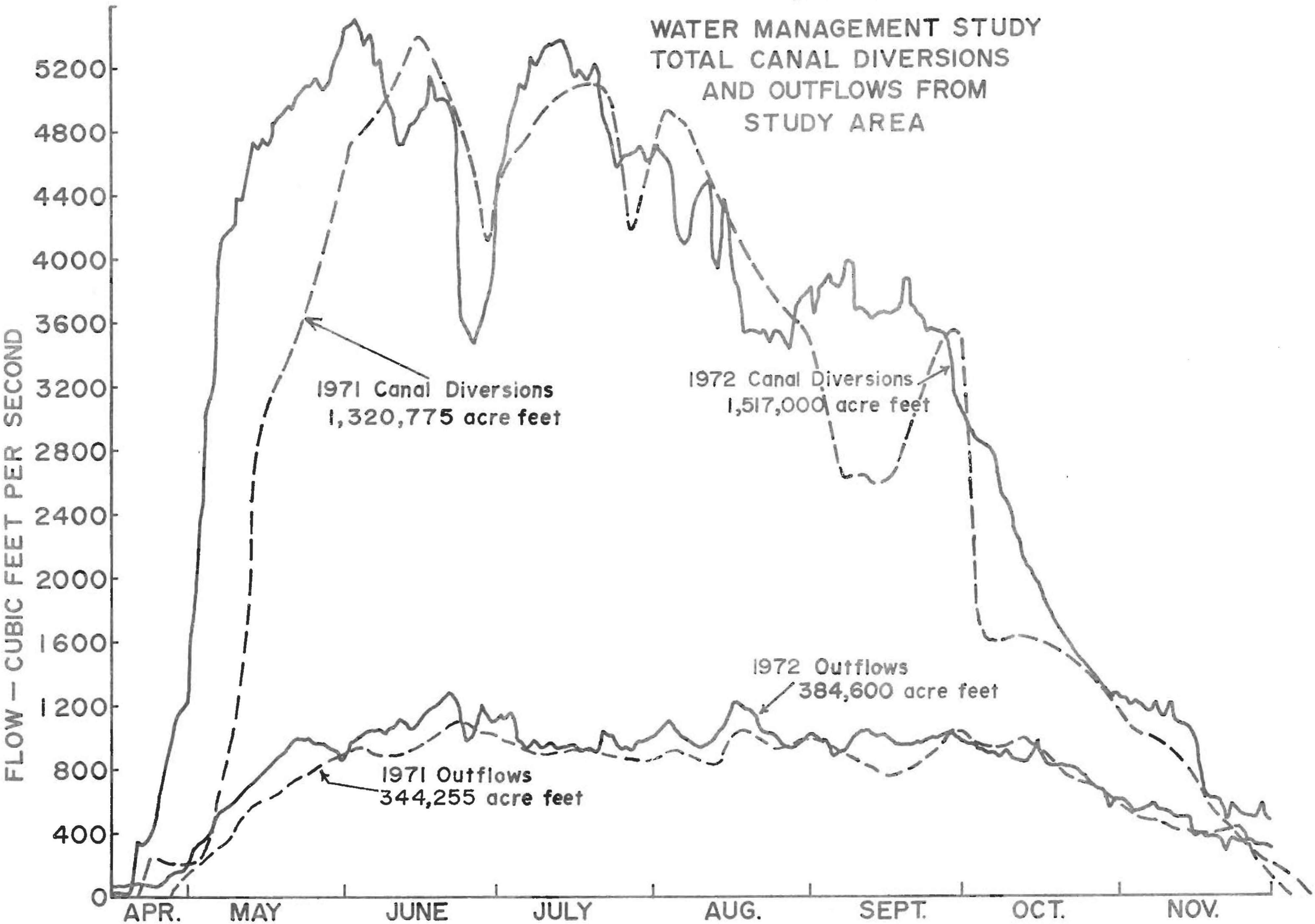
These measurements are performed by District 1 and U. S. Geological Survey personnel. During the 1972 season measurements were extended by the University and ARS personnel past the normal September 30 cutoff date through November 30 or until all canals had been shut down for the winter. Return flows to the Snake River at the Burgess Canal spill, Long Island Slough and Great Feeder were measured through the season. Water leaving the study area to the north by spring flow was measured weekly or bi-weekly by current metering or rated sections. Water transported out of the area to the south in the Anderson, Farmers Friend and Harrison Canals was measured continuously with water stage recorders at rated sections.

Figure 6 shows the three year running average of the published May-September diversions per acre from the Snake River for canals serving about 84,000 acres of the Snake River Fan. May-September diversions and irrigated acres are published in reports of the watermaster for Water District 1. An increasing trend can be observed with the recorded 1972 May-September diversions approaching 13.1 acre feet per acre.

The seasonal distribution of total diversion and outflows for 1971 and 1972 is shown in Figure 7. The total canal diversions include all canals with service areas totally or partially included in the study area. Outflows include return flow to the Snake River and canal flows out of the

Figure 7

WATER MANAGEMENT STUDY
TOTAL CANAL DIVERSIONS
AND OUTFLOWS FROM
STUDY AREA



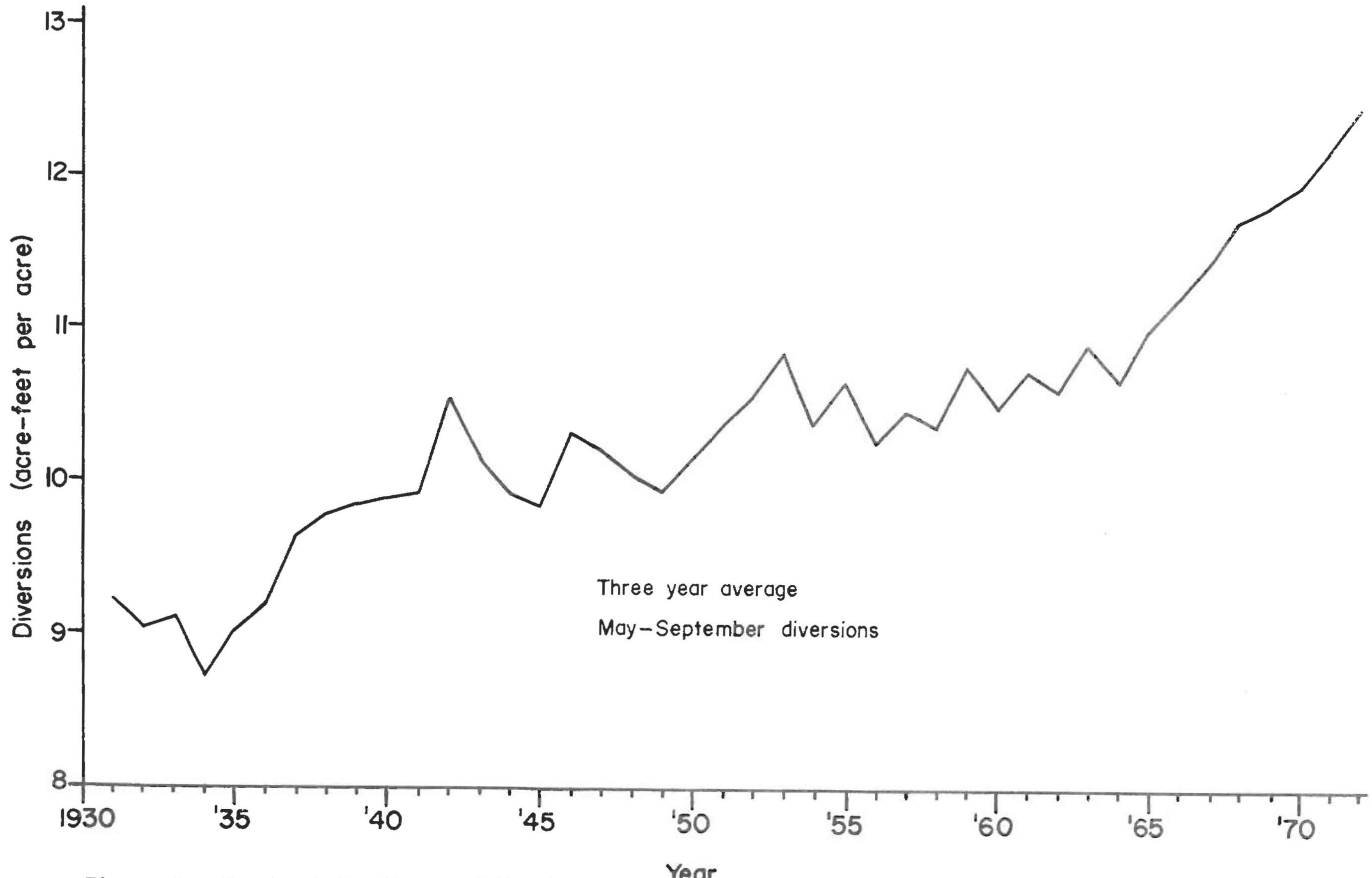



Figure 6. Graph of the Recorded May-September Diversions per Acre from the Snake River for All Canals of the Snake River Fan (Annual Irrigation Diversion).

study area. Clearly noticeable is the decrease in diversion around Pioneer Days, June 24, which is a holiday in the study area. Figures 8 and 9 show the seasonal distribution of the diversions and return flows for the Burgess Canal system and the parks and Lewisville Canal system respectively. The net diversion is calculated as the measured diversion at the canal head gates minus all surface wastes. The distribution of diversions for the 1972 operating season is shown in Table 1.

The total diversion for May-November, 1972, for the 82,250 irrigated acres in the study area was 17.0 acre feet per irrigated acre of which 11.6% was diverted after September 30.

Canal Seepage Losses

The main canals of the systems have a total water surface area of 717 acres or slightly less than 1% of the irrigated area. Wetted areas were determined from large scale aerial photos. Seepage tests were made in 20 locations in the late summer and fall of 1970 and in 16 locations in the early spring of 1971. With an estimated accuracy of measurement between 5% and 10%, seepage measurements averaged 3.50 ft/day. This seepage rate applied to all main canals in the system amounts to 501,500 acre feet over a 200 day season or 33% of the gross diversion.

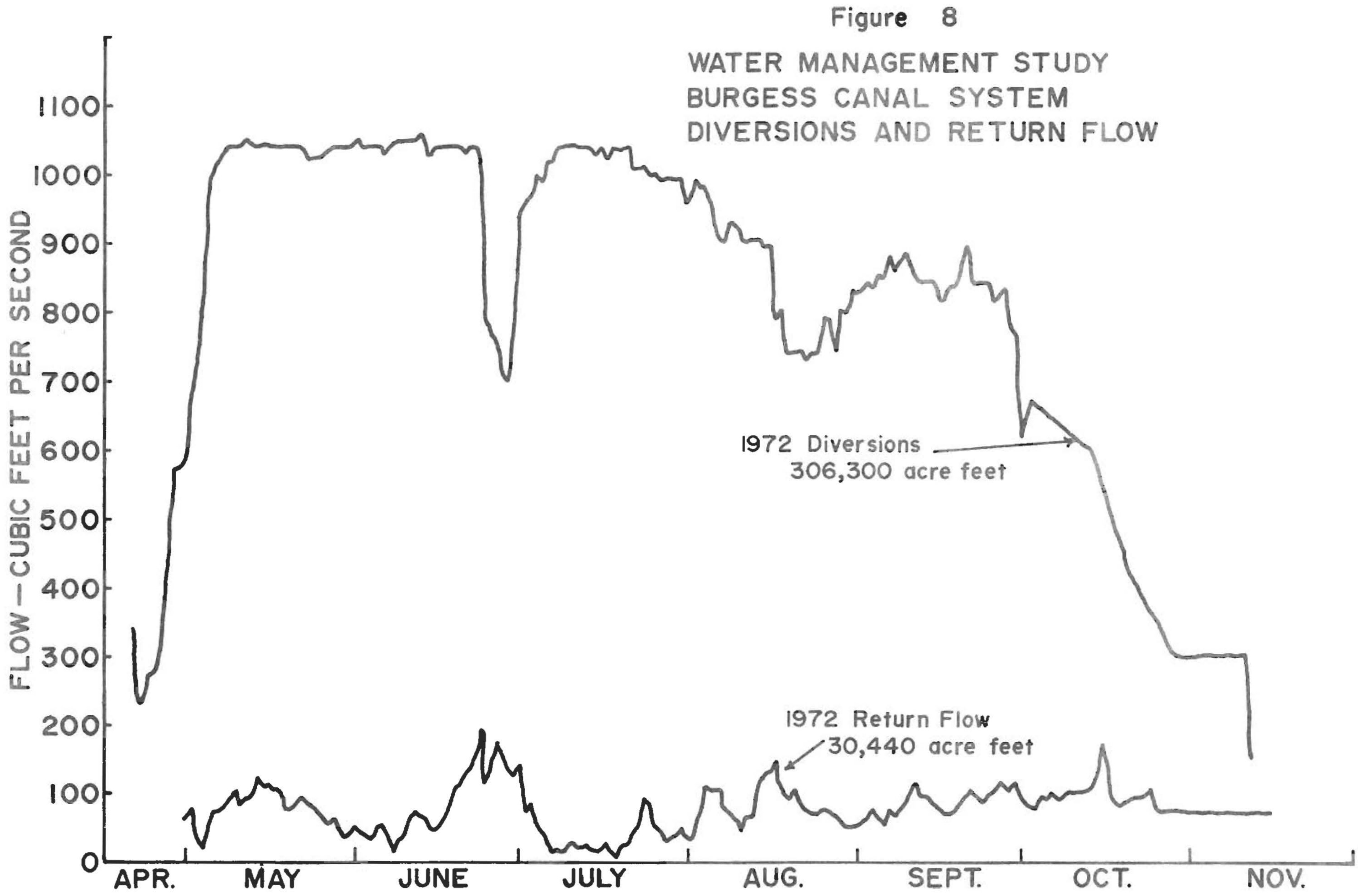


Figure 8
WATER MANAGEMENT STUDY
BURGESS CANAL SYSTEM
DIVERSIONS AND RETURN FLOW
FLOW — CUBIC FEET PER SECOND
1100
1000
900
800
700
600
500
400
300
200
100
0
1972 Diversions
306,300 acre feet
1972 Return Flow
30,440 acre feet
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.

Figure 9

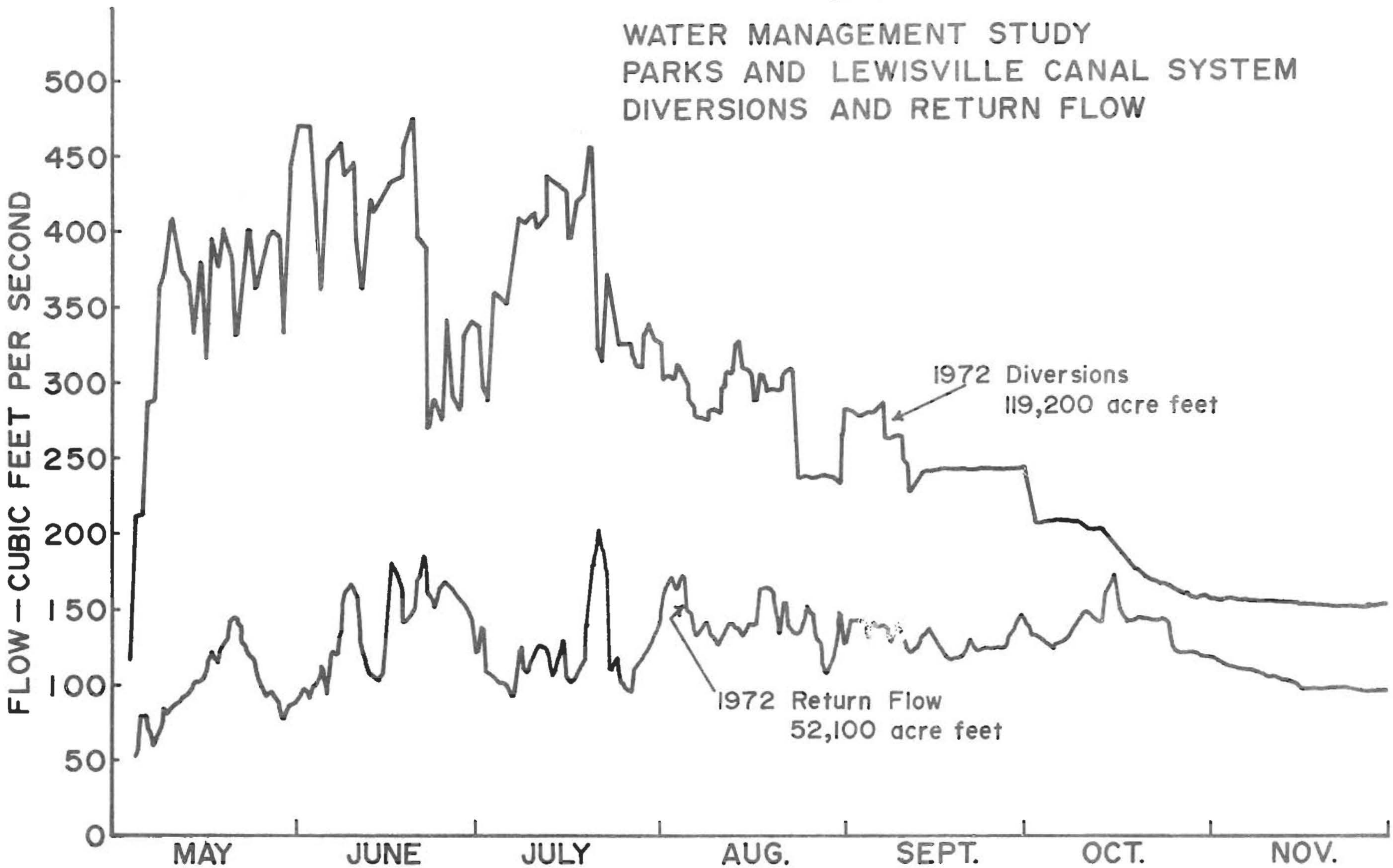

WATER MANAGEMENT STUDY
PARKS AND LEWISVILLE CANAL SYSTEM
DIVERSIONS AND RETURN FLOW
FLOW — CUBIC FEET PER SECOND
500
450
400
350
300
250
200
150
100
50
0
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
1972 Diversions
119,200 acre feet
1972 Return Flow
52,100 acre feet

Table 1

WATER MANAGEMENT STUDY - JEFFERSON COUNTY

| | | |
|---|---|---|
| Irrigated Area = 82, 250 acres | | 1972 |
| Diversion* | 1, 517, 000 af | |
| Outflow** | 384, 600 af | |
| Net Diversion | 1, 132, 400 af | 13. 8 af/a |
| Transmission Loss | 501, 500 af | 6. 1 af/a |
| Net Application | 630, 900 af | 7. 7 af/a |
| Evapotranspiration | 164, 500 af | 2. 0 af/a |
| Deep Percolation | 466, 400 af | 5. 7 af/a |

*Total diversion includes all canals diverting from the Snake River which irrigate or are used to transport water through the study area except the Eagle Rock Canal.

**Outflow includes water transported to lands south of the study area by the Anderson, Farmers Friend, and south branch of the Harrison Canal.

The Great Feeder Canal which has not been accounted for in the above calculation has a wetted area of 311. 6 acres or 31. 5% of the total wetted area of canals. During the latter part of the irrigation season the Great Feeder is a gaining stream and acts like a drain in the western part of the aquifer so that the effective seepage rate over the total length is less than the average for the area. With a seepage rate of 1 ft/day the yearly seepage of the Great Feeder adds 113, 800 acre feet to the aquifer.

Snake River Losses

Recognizing that losses in the Snake River as it flows over the fan can contribute to the groundwater table rise, an attempt was made to evaluate these losses. Stearns (1) in 1938 reported an average loss of 288 cfs in the Heise-Lorenzo reach. Current meter measurements of discharge were obtained three times in 1970 which indicated an average loss of 408 cfs. Based on 408 cfs for a 200 day season, losses from the Snake River account for 163, 200 acre feet of water added to the aquifer.

The Snake River loss represents 21% of the 778, 500 acre feet of water added to the aquifer by seepage from irrigation canals, the Great Feeder, and the Snake River but represents only 13% of the total input of 1, 244, 900 acre feet added to the aquifer over the irrigation season.

Evapotranspiration

Crop evapotranspiration for the 1972 season was calculated using the Penman conbination equation (2) with crop coefficients based on the measured crop distribution. Differences in crop distribution throughout the area were not significant. The total evapotranspiration for the season was 2. 0 acre feet per acre or 164, 500 acre feet for the study area.

# SYSTEM SIMULATION

In order to efficiently determine and evaluate the alternative solutions for relieving the high groundwater table, a method of predicting the response of the aquifer to varying degrees of change in the input and output was necessary.

Analytical solutions to the basic flow equations are not applicable because of a high degree of simplification needed to secure a solution for the complex hydrogeologic system with varying boundary conditions.

Analog models of the resistance-capacitance type are applicable although construction of an analog for a specific aquifer is costly and the size and flexibility required for this study would be difficult to achieve. With an analog model it is not possible, other than on a trial and error basis, to calibrate the model to simulate historical trends. The trial and error calibration is cumbersome if not impossible so it would be necessary to incorporate some hybrid computer technique to achieve a reasonable calibration.

The availability of large digital computers and new finite difference techniques for solving the flow equations make a digital model most feasible since all objectives can be met on the same facility and the model designed can be general enough to be applied to other aquifers.

The model designed is a mathematical digital model that incorporates a procedure for automatic parameter adjustment so that it is possible to simulate historical water table response of any year on record. Historical water level data show that the seasonal rise of the groundwater table is a repetitive cycle of which the yearly amplitude is nearly constant so that selection of any particular year or years for calibration is immaterial.

For the study area the year May 1, 1972, - April 30, 1973, was chosen for calibration since for this year more reliable data was collected to verify the simulation. With a calibrated model it was then possible to study the effects of change in water management on the groundwater flow.

Model Description

The mathematical model developed is a finite difference digital model and, like models of Bredehoeft and Pinder (3), it is based on the alternating direction implicit method as introduced by Peaceman and Rachford (4) and Douglas and Rachford (5) and calculates head values on a gridpoint basis.

The two dimensional model accommodates non-homogeneous, confined and unconfined, leaky and non-leaky aquifers. All boundary conditions normally encountered can be handled such as constant head boundaries, impermeable boundaries, and boundaries formed by lakes and streams in which the water level changes in time. A new procedure for treatment of flow boundary through which flow is variable and a function of the "upgradient" flow regime has been developed. An option for simulating an open drain is included in which the drain functions as a constant head any time when the water table around the drain is higher than the specified water level in the drain.

Leakage from or to an underlying or overlying water bearing formation is dependent on the hydraulic head in the aquifer and is generated in the model program. It is assumed that the head in the adjacent formation is constant during the simulation period.

Inputs or outputs not dependent on the hydraulic head include precipitation, irrigation application, crop evapotranspiration, well discharges or recharges, constant leakage if present, inputs or outputs due to change of average water content of the soil profile above the water table and canal seepage (6). Canal seepage is dependent on the water table levels and can be calculated in the model program as such. Calculation procedures by other authors (7) (8) (9) assume unsaturated flow beneath the canal; however, data on unsaturated vertical hydraulic conductivity is generally lacking. Because the canal operating procedures for this study area result in nearly constant wetted canal perimeters, seepage is assumed to be constant as measured in the field.

Irrigation applications on the many different irrigation districts and the geology vary substantially so that the maximum amplitude of the water table rise varies from 5 to 50 feet and occurs at different times at each node point. Therefore it was considered necessary to approximate as accurately as possible input for each node at each time step.

Data on climate, soils, crop distribution, irrigation diversions and distribution losses are utilized in a separate input program to calculate a three dimensional source term which serves as input to the main program. The main program is general enough to be applied to any aquifer. The separate input program allows greater flexibility in evaluating inputs because it can be tailored to the specific characteristics of an aquifer without changing the main program. The alteration of an input routine that is incorporated directly into the model program many times jeopardizes the operation of the model program.

The differential equation governing the nonsteady flow in an elastic non-homogeneous porous medium can be written as

$$\frac{\alpha}{\alpha x_i}\left(K_{i,j}\frac{\alpha h}{\alpha x_j}\right) = \frac{1}{b_{(i,j,t)}}\left(S\frac{\alpha h}{\alpha t}\right) + W_{(i,j,t)} \qquad (1)$$

$K_{i,j}$ is hydraulic conductivity tensor (L/T)

$h$ is hydraulic head (L)

$S$ is the storage coefficient (dimensionless) b is the depth of aquifer (L)

W is the volume flux per unit area (L/T).

If the coordinate axes are aligned with the principal directions of the conductivity tensor and with $T_{(x,y)} = K_{(x,y)}\, b_{(x,y,t)}$, the finite difference approximations to equation (1) can be written as

$$T_{xx\, i+1/2,j} \frac{(h_{i+1,j,k} - h_{i,j,k})}{(\Delta x)^2} + T_{xx\, i-1/2,j} \frac{(h_{i-1,j,k} - h_{i,j,k})}{(\Delta x)^2} \tag{2}$$

$$+ T_{yy\, i,j+1/2} \frac{(h_{i,j+1,k} - h_{i,j,k})}{(\Delta y)^2} + T_{yy\, i,j-1/2} \frac{(h_{i,j-1,k} - h_{i,j,k})}{(\Delta y)^2}$$

$$= S_{i,j} \frac{(h_{i,j,k} - h_{i,j,k-1})}{\Delta t} + \frac{Q_{i,j,k}}{\Delta x \Delta y \Delta t} - \frac{Kv_{i,j}}{2 B_{i,j}} (2Hc_{i,j} - h_{i,j,k} - h_{i,j,k-1})$$

where i is the index in the x dimension.

j is the index in the y dimension.

Kv is the vertical hydraulic conductivity of the restricting layer (L/T).

B is the thickness of the restricting layer (L).

$\frac{Kv}{B}$ the impedance of the restricting layer separating the aquifers (L/T).

Hc is the hydraulic head of the underlying or overlying aquifer.

$Q_{i,j,k}$ is the input term ($L^3$), in cubic feet for every node point at every timestep.

Above equation implies an implicit method of solution. Since an implicit solution for large grid systems requires a considerable amount of computation time, the alternating direction implicit method (4), (5) is preferable since it results in a system of equations with a tridiagonal coefficient matrix for which a simple alogorithm exists.

Essentially the principle is to employ two difference equations which are used in turn over successive type steps, each of duration $\Delta t/2$.

The first equation is implicit only in the x-direction and solves row by row for intermediate values of $h_{i,j}$ at $t = k+1/2$ which are used in the second equation, implicit in y-direction solving now column by column, leading to the solution of $h_{i,j,k+1}$ at the end of the whole time interval $\Delta t$. Equation (2) for a row calculation in the alternating direction implicit method with coefficients A, B, C and D substituted for all known value yields

$$Ah_{i-j,k+1/2} + Bh_{i,j,k+1/2} + Ch_{i+1,j,k+1/2} = D \qquad (3)$$

The hydraulic head is calculated in a system of tridiagonal equations similar to equation (3) in which the boundary equations have only two unknowns.

## Boundary Conditions

Boundary conditions and interior and exterior nodes are denoted in the program by specific numbers in input arrays. According to the number associated with a node point the coefficients A, B, C and D of equation (3) are calculated. This method allows for recognizing all boundary conditions described above and by changing the node designation during a simulation period, boundaries change accordingly. This is particularly helpful in the simulation of a surface drain in the study area, since a drain requires different treatment according to the calculated water table levels at the drain site.

When flow across a boundary occurs, the head at the boundary changes and some function defining the head at the boundary becomes necessary. In calculating the hydraulic head by cutting off the aquifer at boundary node, (ib, j), three unknowns remain in equation (3) since nothing is known about node point (ib-1, j) (Figure 10). To eliminate one unknown, $h_{ib-1, j, k+1/2}$ is expressed in terms of $h_{ib, j, k+1/2}$ and $h_{ib+1, j, k+1/2}$ using hydraulic head values calculated in the previous timestep. If the change in hydraulic head per timestep is not abrupt in the vicinity of the flow boundary, it follows that as a first approximation,

$$\frac{\alpha 1}{\beta 2} = \frac{\alpha 1}{\beta 2}$$

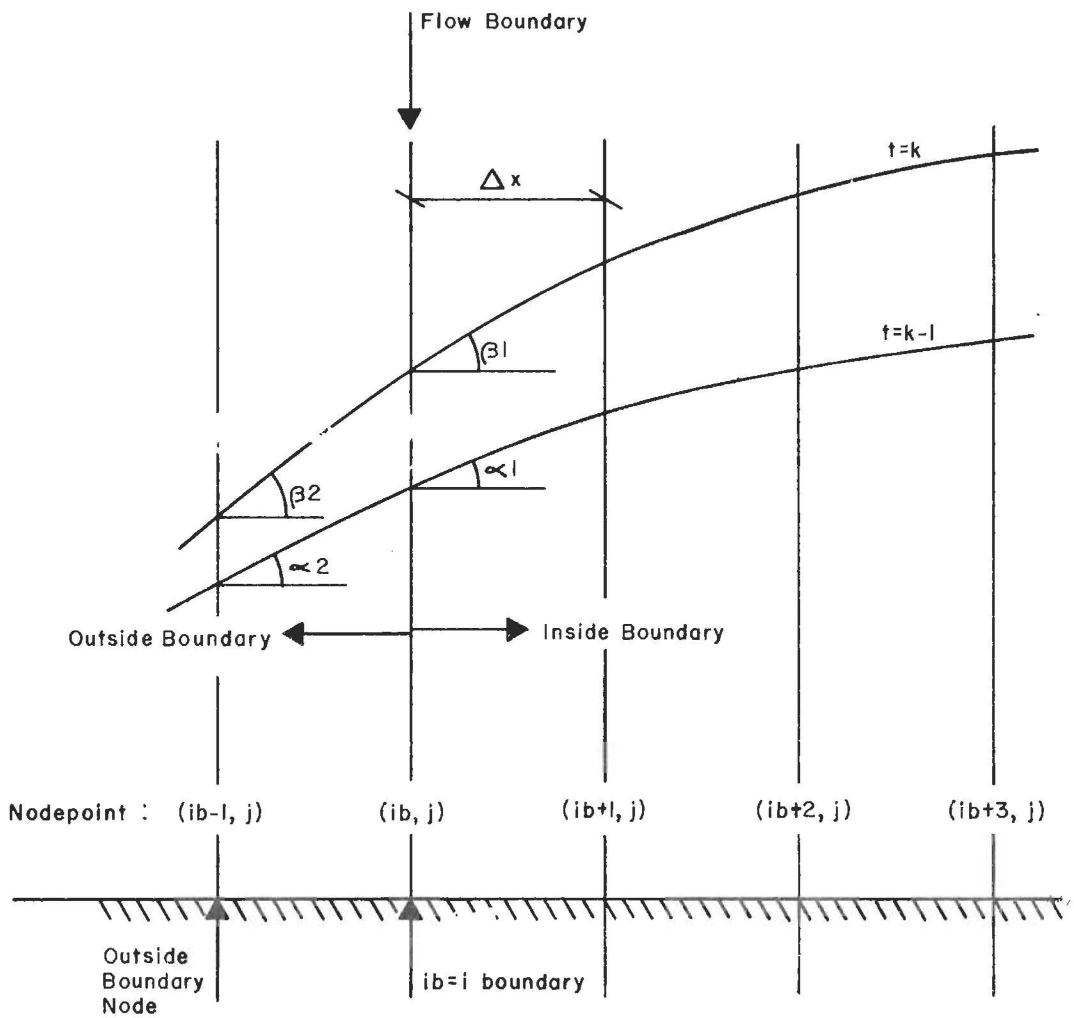



Figure 10. Hydraulic Head in the Vicinity of the Flow Boundary.

$\alpha 1$ and $\alpha 2$ are the average gradients of the water table in the previous half time step (k)

$$\text{then:} \quad \beta 2 = \frac{\alpha 2}{\alpha 1} \quad \beta 1 \quad \frac{\alpha 2}{\alpha 1} = \frac{h_{ib,j,k} - h_{ib-1,j,k}}{h_{ib+1,j,k} - h_{ib,j,k}} \qquad (4)$$

$$\text{and} \quad h_{ib-1,j,k+1/2} = h_{ib,j,k+1/2} - \beta 2 \;(\Delta x) \qquad \text{or}$$

$$h_{ib-1,j,k+1/2} = h_{ib,j,k+1/2} - \frac{\alpha 2}{\alpha 1} \left(h_{ib+1,j,k+1/2} - h_{ib,j,k+1/2}\right)$$

Substituting expression (4) in equation (3) yields a boundary equation with two unknowns

$$B' \; h_{ib,j,k+1/2} + C' \; h_{ib+1,j,k+1/2} = D \qquad (5)$$

The equation now calculates for $t = k+1/2$, head values for nodes ib, ib + 1, ib + 2, . . . . . . . .

As a second approximation, $h_{ib-1,j,k+1/2}$ can be calculated using the node points ib, ib+1, ib+2 with a quadratic function. This second approximation is used for the next timesteps. When highly unsteady state conditions exist at the flow boundary as a result of incorrect values of hydrogeological parameters T and S, the computation becomes unstable.

Therefore a check of the $(\alpha 2/\alpha 1)$ ratio is introduced as well as upper and lower limits for the head differences between succeeding node points used in this approximation. Testing of the procedure led to very satisfactory results (6).

Instead of approximating $h_{ib-1, j, k+1/2}$ with the ratio method, it may be approximated by solving equation (1) for node ib-1, j using forward or backward difference techniques. Since this method is partly explicit, stability may be a problem and is being investigated.

For management purposes the option of including a surface drain was incorporated in the model. The assumption is made that the drain is installed in the most efficient way so that the rising water table will intersect the drain over the whole length at approximately the same time. The drain operates as a constant head any time that the average water table elevation in the immediate area is equal to or greater than the stipulated elevation of the drain.

Boundaries for Snake River Fan

Figure 11 is a map of the study area with a one mile square grid imposed. The Snake River serves as a boundary with a variable water level adjusted according to the river management, and the southeast part of the aquifer is bounded by a mountainous area which serves as an impermeable boundary.

In the southwest corner the gravel aquifer connects with the deep ground-water table of the Snake River Plain basalts. The gradient is steep and generally in a southwest direction. The boundary is composed of two types: (1) an artificial no-flow boundary which parallels the direction of flow and (2) the flow boundary which terminates the southeast portion of the study area.

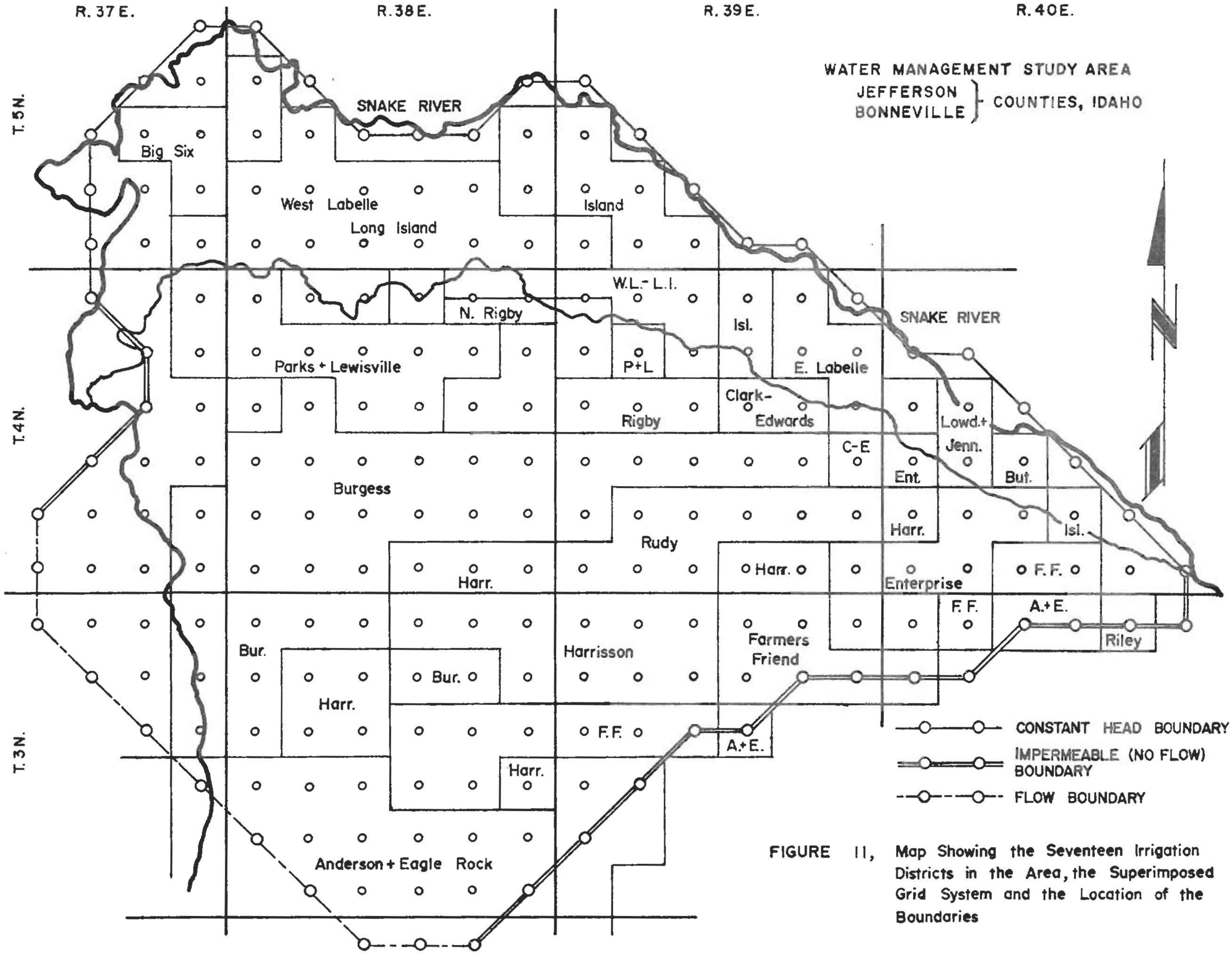



FIGURE 11, Map Showing the Seventeen Irrigation Districts in the Area, the Superimposed Grid System and the Location of the Boundaries

Calibration Routine

The data for the study area is composed of inputs associated with water management which are calculated in the input program, and data related to the geohydrological properties of the aquifer such as the hydraulic conductivity, storage coefficients, and aquifer bottom elevations, the impedance of the restricting layer, the initial head difference between aquifers and the initial water table values.

Historical records are available from a network of wells; however, information about the geohydrological parameters is extremely scarce. In applying the model an initial estimate for the parameters was made. Water balance computations indicated that a major proportion of the total water transfer is drawn from this area by leakage into the regional water table.

Investigation of the effects of management changes on aquifer behavior is only possible if the model is able to simulate the historical behavior of the aquifer. Where geological data is scarce, adjustment of aquifer parameters to achieve simulation of historical behavior is difficult without a systematic calibration routine.

The calibration routine developed for this model changes aquifer parameters based on differences in calculated and historical water table elevations at selected timesteps. Because of the seasonal response of this aquifer, water levels at three timesteps were chosen for comparison: the maximum, an intermediate stage and the minimum at the end of the yearly cycle. Figure 12 shows the aquifer response for the Jay Clark well near Rigby. At each selected timestep for every node point the deviations from historical water table elevations are calculated as well as the sum of squares of the deviations over the entire aquifer.

Four parameters were considered for change: conductivity, storage coefficient, impedance, and initial head difference. Parameter values are changed according to the magnitude of the deviations at one of the selected timesteps. In this area with a high water table problem best fit priority was given to the maximum water table elevation, which occurs approximately August 30.

The selected period for calibration of the model was May 1, 1972, to May 1, 1973. The deviations from historic values for the three selected timesteps are stored for every node. Conductivity values are changed based on deviations from the maximum historical water table. The new values of conductivity are calculated for every node point by the relationship:

$$K_{new} = K_{old} + K_{old} \left( \frac{\text{node point deviation}}{\text{maximum deviation in the aquifer}} \right)$$

Conductivity values are adjusted in four simulation runs and the routine selects that set of conductivity values that resulted in the minimum overall sums of squares for all three timesteps.

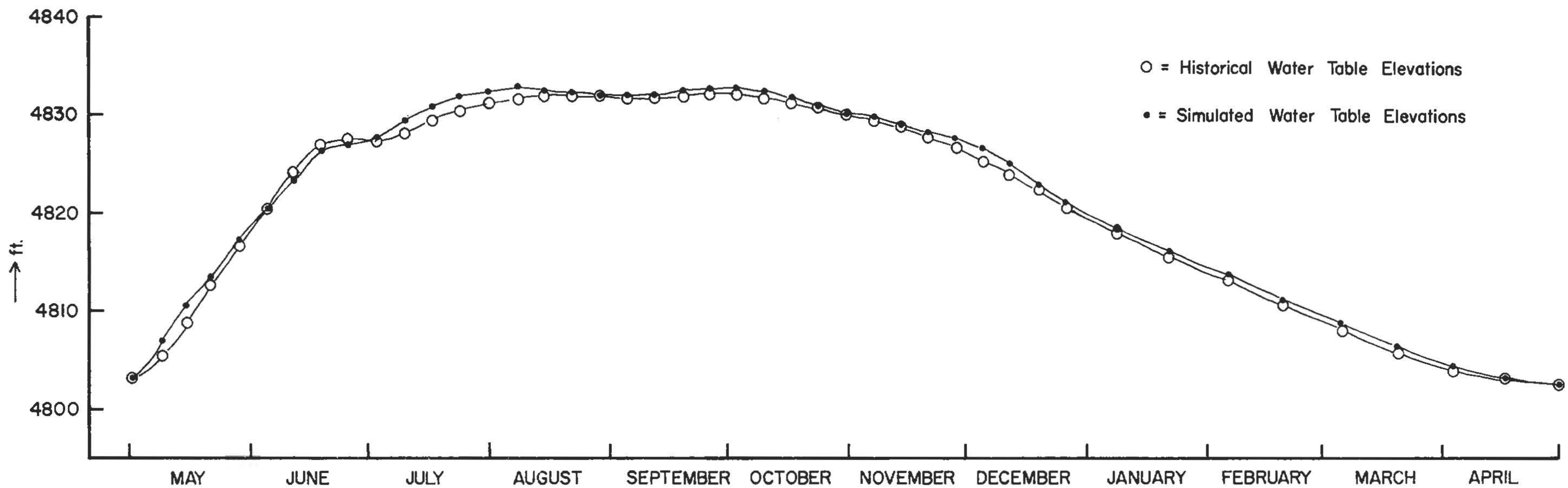



Figure 12. Historical And Simulated Water Table Elevations —— Jay Clark Well

The routine then changes the conductivity values back to the original starting values and a second parameter is adjusted similarly in four simulation runs. The remaining two parameters are adjusted in the same manner. At the termination of the first calibration these 16 simulation runs result in a set of data cards that gives the least overall sum of squares of deviations over the three timesteps for each parameter.

The initial data set of these parameters is replaced by the result of the first calibration and a second calibration is made. This procedure is followed until no decrease in total sum of squares is observed.

An example of the results of the calibration is given in Figure 13 which is a microfilm plot showing the deviations for four calibrations of the impedance factor at a particular node point. Deviations calculated from measured head values at four timesteps are plotted. The first timestep represents the start of the simulation (May 1, 1972); the second timestep is the timestep at which the maximum water table rise occurs (August 30); the third timestep (October 30) is an intermediate stage; while the fourth timestep represents the completion of the yearly cycle (May 1, 1973). The total sum of squares of the deviations is calculated for the second, third, and fourth timesteps. The groups of numbers (1, 2, 3, 4) represent the deviations from measured values as a result of runs with successive parameter values.

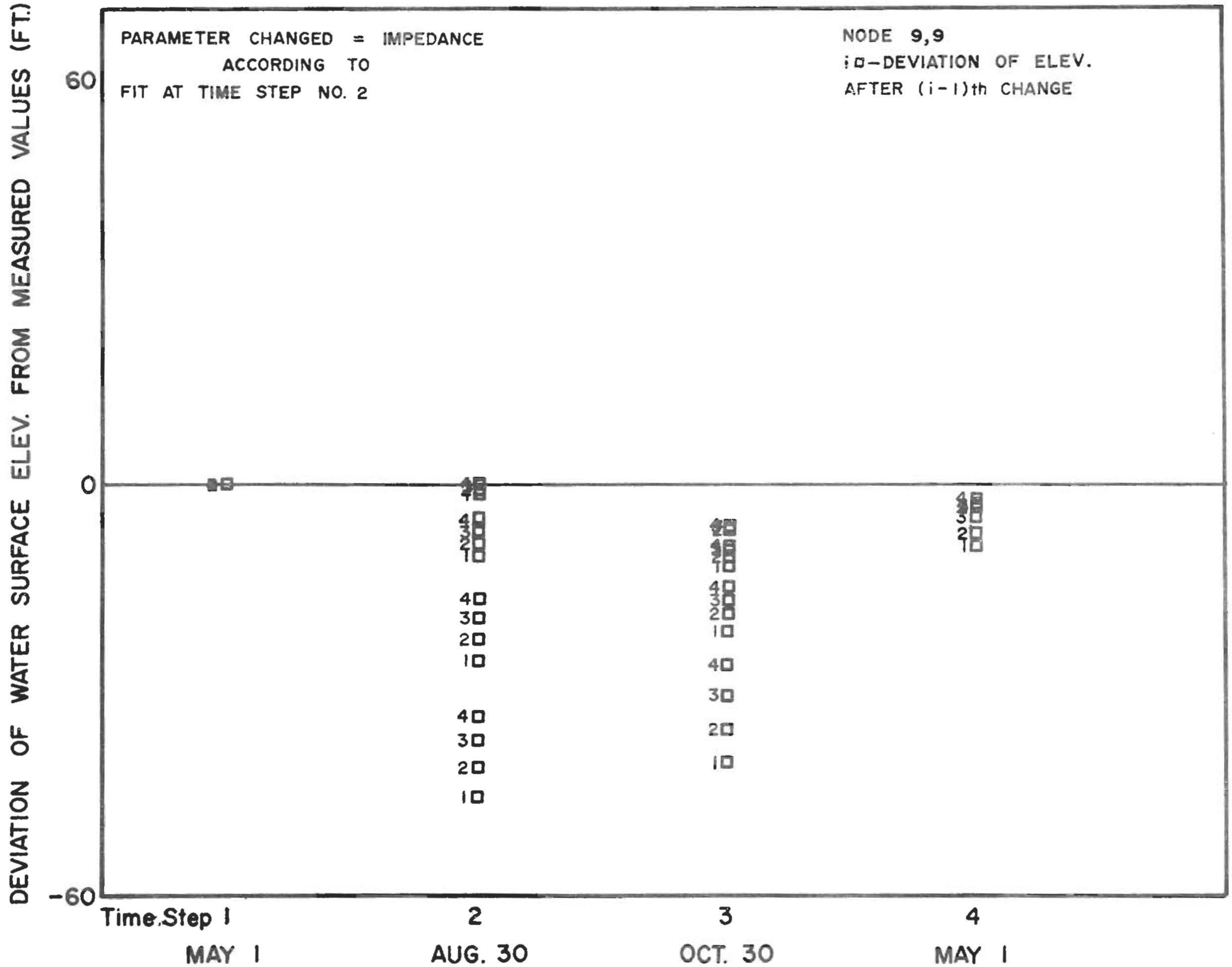



Figure 13. Deviations of Calculated from Measured Head Values at Four Time Steps During Four Calibrations

A point by point calibration results in a very satisfactory fit. Even though the parameters are changed according to the fit at the second timestep, the deviations at other timesteps also decrease. Graphs of the four calibrations for the other parameters (conductivity, storage coefficient, head difference) show similar results. The four calibration runs showed that the third and fourth parameter (impedance and initial head difference of leaky aquifer) were most sensitive to change while the conductivity values were least sensitive. A change of conductivity values based on average hydraulic gradient compared to historic gradient instead of change based on head comparison is now incorporated in the model and gives greater sensitivity to changes in conductivity.

From the last calibration run on the Snake River Fan aquifer the final sum of squares of deviations resulted in an average deviation from historical values of 1. 25 ft. for the second timestep (August 30); 3. 2 ft. for the third timestep (October 30); and 4. 4 ft. for the fourth timestep (April 30, 1973). Since the maximum rise of the groundwater table in the aquifer varies from 20 to 50 ft. except near the Snake River, this result is satisfactory.

Figure 12 shows the historical well hydrograph and the simulated water table elevations after final calibration for the year 1972 of the Jay Clark well located in the study area. Figure 12 also shows the close simulation of the historical water table representative for the matching of the historical water table over the whole area and forms a reliable basis for evaluating management decisions. Figures 14 and 15 are the microfilm plots of the simulated minimum and maximum water table elevations which occur about April 30 and August 30 respectively.

## Input Program

The input term Q(i, j, k) which is calculated in the input program for every node point (i, j) at every half timestep (k) can be written as follows:

$$Q(i, j, k) = QI(i, j, k) - QS(i, j, k) - PE\ (i, j, k) + E\ (i, j, k) + AMO\ (i, j, k) + PUM\ (i, j, k) - QCL\ (i, j)$$

where

- QI = input due to irrigation at each node during time increment (k-1) to k.
- QS = input due to canal seepage at each node for time increment (k-1) to k.
- PE = precipitation
- E = crop evapotranspiration
- AMO = change of average water content in soil profile above the water table.
- PUM = output or input due to a pumped well or recharge well at node i, j for time increment (k-1) to k.
- QCL = input or output due to a leaky aquifer (constant in time).

The specific methods to calculate these inputs are outlined in de Sonneville (6). For the calibration of the geohydrological parameters the year from May 1, 1972, to May 1, 1973, was used, and inputs were

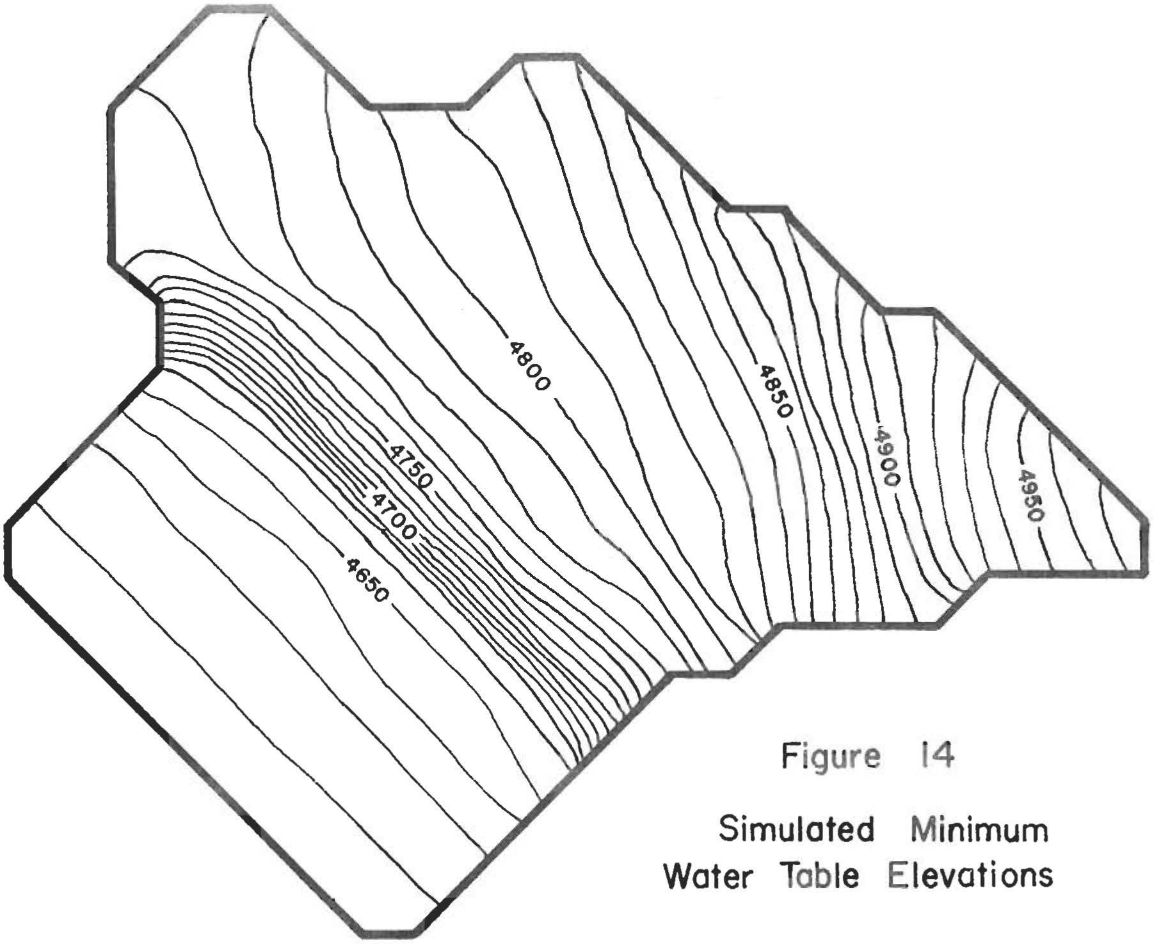



Figure 14

Simulated Minimum Water Table Elevations

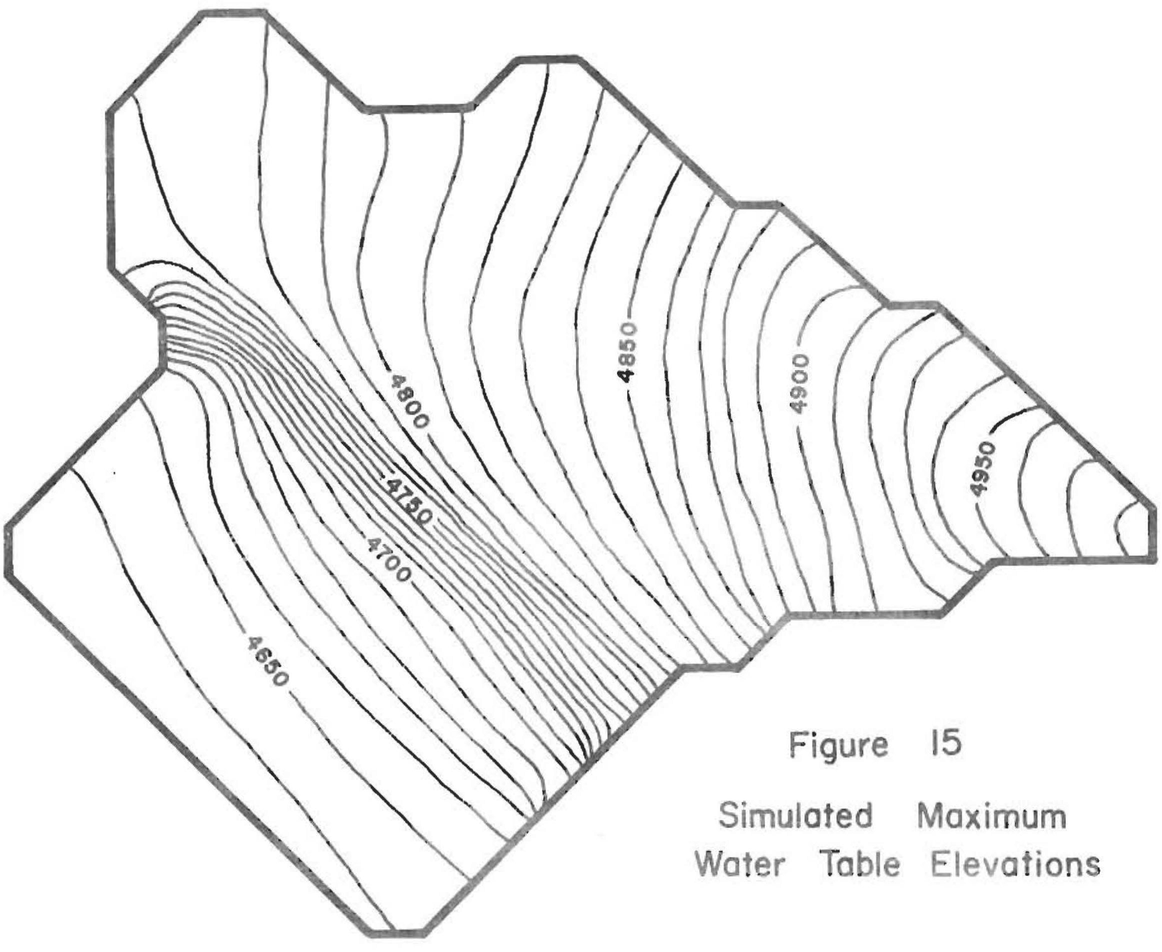



Figure 15

Simulated Maximum Water Table Elevations generated for weekly half timesteps from May 1 to December 11 which is the irrigation season. From December 11 to May 1 which is the winter season inputs were calculated for two week half timesteps.

The start of simulation was chosen at May 1 since this date represents the low point of the recession curve of the water table before the water levels rise again as a result of irrigation diversions. Diversions take place until at least November 25 or later, so the irrigation season in the model is extended to December 11. From December 11 to May 1 no irrigation takes place and the evapotranspiration is considered negligible. Table 2 shows the two seasons for a year simulation.

Table 2

TIME TABLE OF THE TWO SEASONS FOR COMPUTER MODEL

| Half timestep No: | | k | | | k | | | k |
|---|---|---|---|---|---|---|---|---|
| Start May | 1 | 1 | Sept. | 11 | 20 | Jan. | 22 | 36 |
| | 8 | 2 | | 18 | 21 | | 29 | |
| | 15 | 3 | | 25 | 22 | Feb. | 5 | 37 |
| | 22 | 4 | Oct. | 2 | 23 | | 12 | |
| | 29 | 5 | | 9 | 24 | | 19 | 38 |
| June | 5 | 6 | | 16 | 25 | | 26 | |
| | 12 | 7 | | 23 | 26 | Mar. | 5 | 39 |
| | 19 | 8 | | 30 | 27 | | 12 | |
| | 26 | 9 | Nov. | 6 | 28 | | 19 | 40 |
| July | 3 | 10 | | 13 | 29 | | 26 | |
| | 10 | 11 | | 20 | 30 | Apr. | 2 | 41 |
| | 17 | 12 | | 27 | 31 | | 9 | |
| | 24 | 13 | Dec. | 4 | 32 | | 16 | 42 |
| | 31 | 14 | | 11 | 33 | | 23 | |
| Aug. | 7 | 15 | | 18 | | | 30 | 43 |
| | 14 | 16 | | 25 | 34 | | | |
| | 21 | 17 | Jan. | 1 | | | | |
| | 28 | 18 | | 8 | 35 | | | |
| Sept. | 4 | 19 | | 15 | | | | |

## RESPONSE TO WATER MANAGEMENT CHANGES

The data for the input program was changed accordingly for every management alternative. Inputs are the final calibrated values of the hydro-geological parameters, the initial head values of May 1, 1972, and the magnetic input tape which is different for every management alternative.

With these inputs the management model calculates new head values for all timesteps in the yearly cycle and prints out the deviations of the management-calculated water table elevations from the 1972 water table elevations for three selected timesteps for every node point.

The deviations calculated from historical head values for the three selected timesteps are transferred to a subroutine that generates a contour plot of the deviations on microfilm. The selection of specific reasonable management alternatives was made by the University and the ARS utilizing information about the study area and the suggestions of the local people.

<u>Alternative 1 - Two foot reduction of Snake River Water Levels</u>

The survey questionnaire of local residents indicated that the possible cause of the groundwater table problem was the high water level of the Snake River. This suggestion was investigated by modeling the Snake River at a level two feet lower than the 1972 actual level at all points of the river during the total yearly cycle.

The model run shows a lowering of the maximum water table of about one foot at one mile distance from the river and about 0.5 foot at two miles distance from the river. A contour plot of deviations from historical maximum water table elevations is shown in Figure 16. Except for an influence strip parallel to the Snake River, the calculated maximum water table equals the historical maximum water table.

<u>Alternative 2 - Lining of all Canals</u>

The dense network of irrigation canals constructed in coarse gravels amount to 717 acres of canal with an average seepage rate of 3.5 ft/day. Seepage amounts to 501,500 acre feet or 6.1 acre feet per acre over the area and is a major contributing factor to the high water table problem.

This alternative involves the lining of canals of all irrigation districts in the Snake River Fan to determine the relative contribution of canal seepage to the water table rise in the aquifer. A considerable lowering of the maximum water table over the entire area as compared to the historical maximum occurs. Three to four foot decreases occur in the area north of the Great Feeder Canal. In the vicinity of Rigby the water table is 10-15 feet lower and near Ririe about 12 feet. Figure 17 is a contour plot of deviations from historical maximum water tables and shows clearly the overall lowering due to the lining of canals. Where the groundwater table of the study area connects with the regional groundwater table of the Snake Plain aquifer, the water table is 7 feet lower. Figure 18 is a

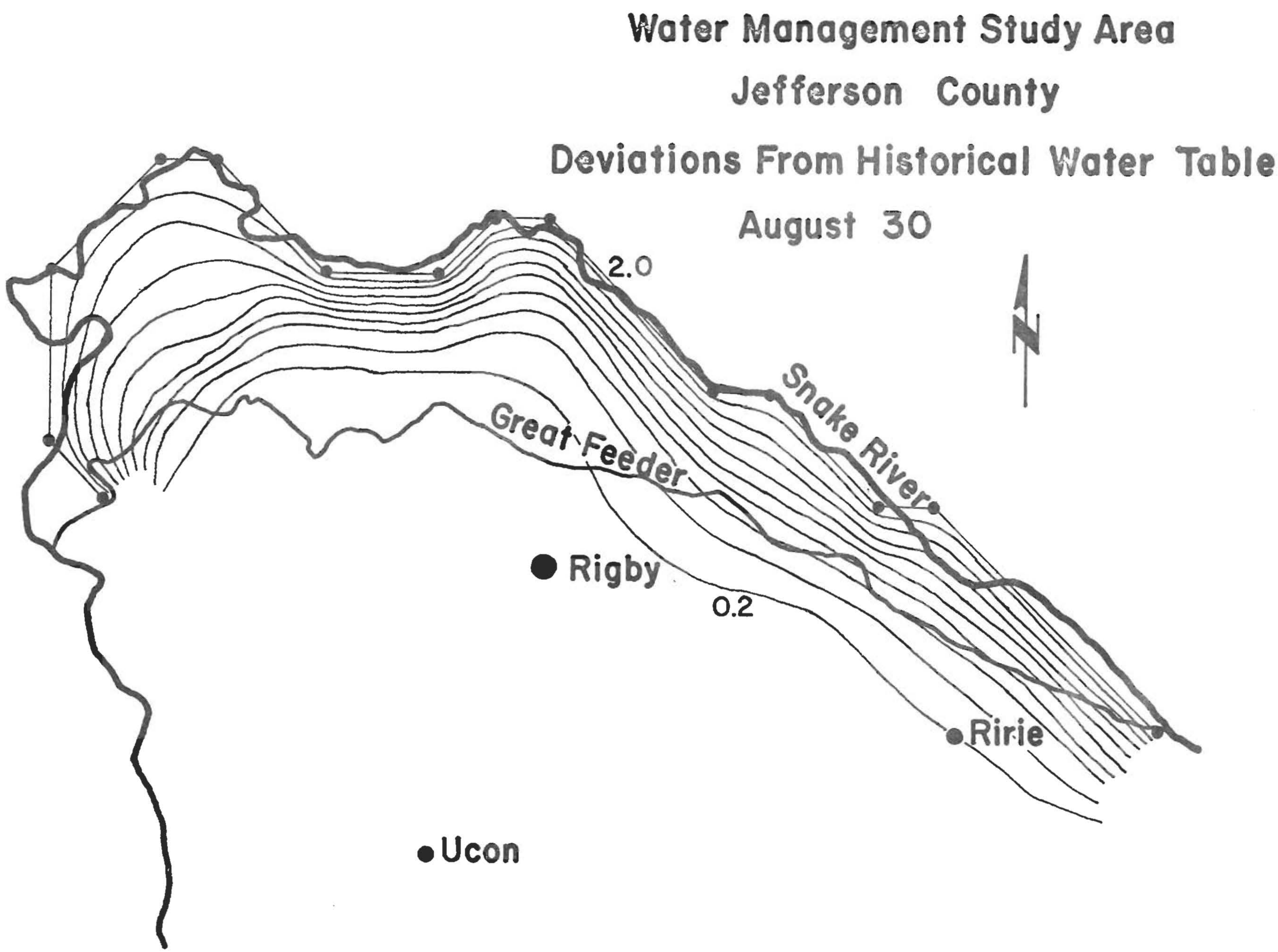



Figure 16 2 Ft Reduction Of River Stage — Alternative 1

## Water Management Study Area
## Jefferson County

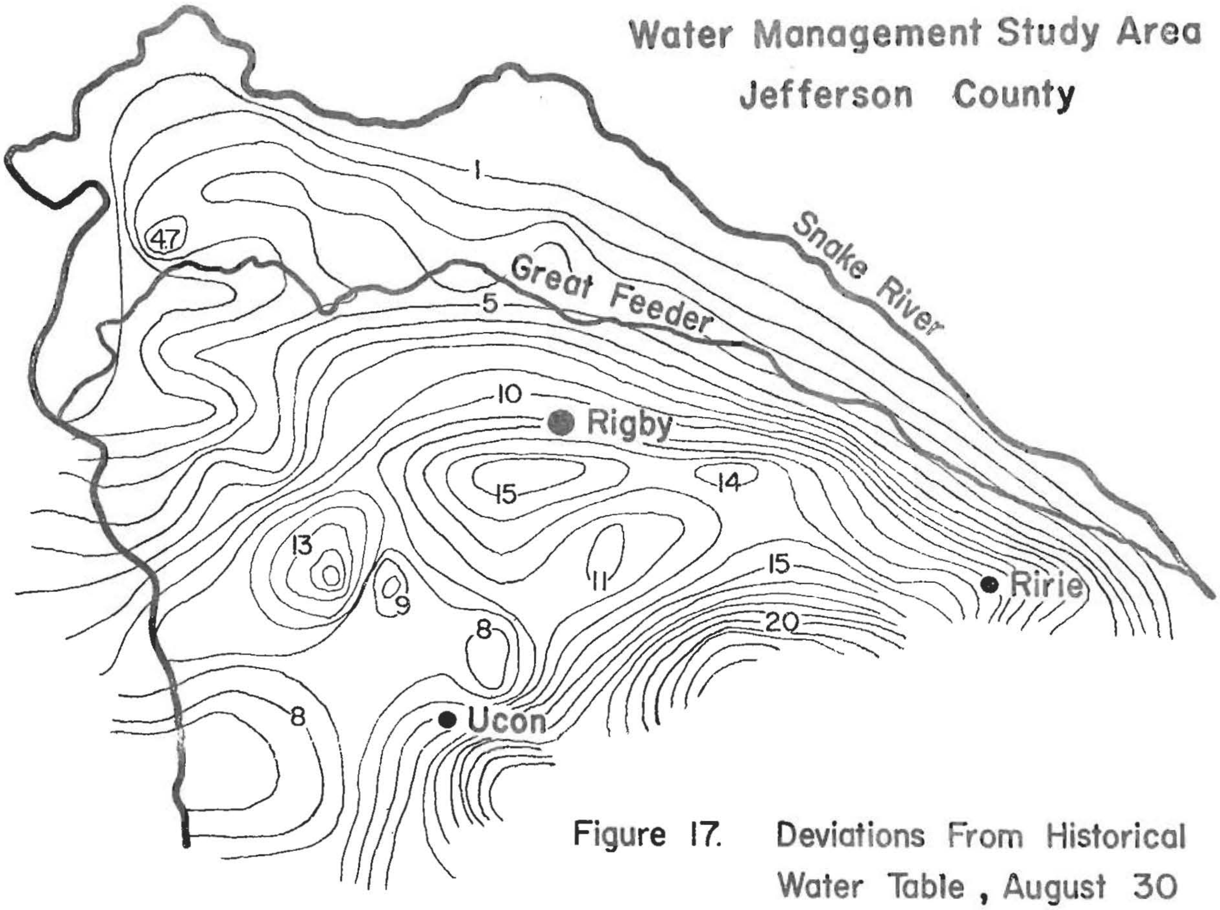



Figure 17. Deviations From Historical Water Table, August 30

Lining Of All Canals—Alternative 2

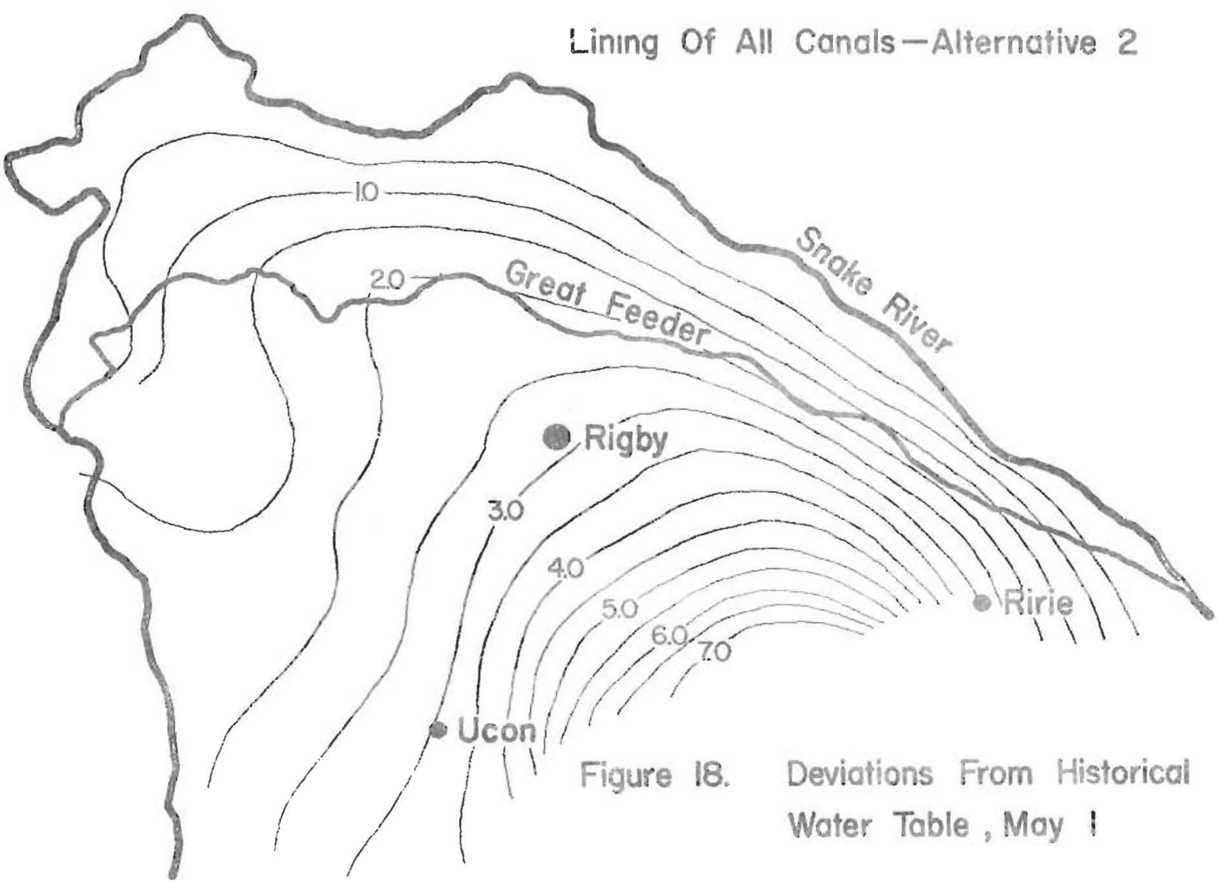



Figure 18. Deviations From Historical Water Table, May 1

Lining Of All Canals—Alternative 2

contour plot of deviations from the minimum historical water table at the end of the simulation before the start of the new irrigation season. The calculated water table is lower than the minimum historical water table. The elimination of seepage represents a 33% reduction of the total diversions to the area. Because of this large reduction there is less recharge to the groundwater table and the water levels at the end of the simulation follow part of a recession curve lower than the historical recession curve before rising again as a result of the irrigation in the next season. This lower minimum water table influences the maximum water table of the next year and is investigated in management alternatives 11 and 13.

Alternative 3 - Lining of Canals near Ririe

The area around the City of Ririe has a high water table problem, partially caused by the seepage of a dense network of irrigation canals that originate from the Snake River. To achieve local relief of the high water table at Ririe, a solution may be the lining of all canals near the city; these are the canals in the sections 32 through 36 of T 4N, R 40E and sections 1, 2, 5 of T 3N, R 40E.

This alternative results in a calculated water table that is 10 feet lower than the historical maximum at the location of Ririe while the influence of the canal lining stretches out about three miles in any direction. Figure 19 represents a contour plot of deviations from historical

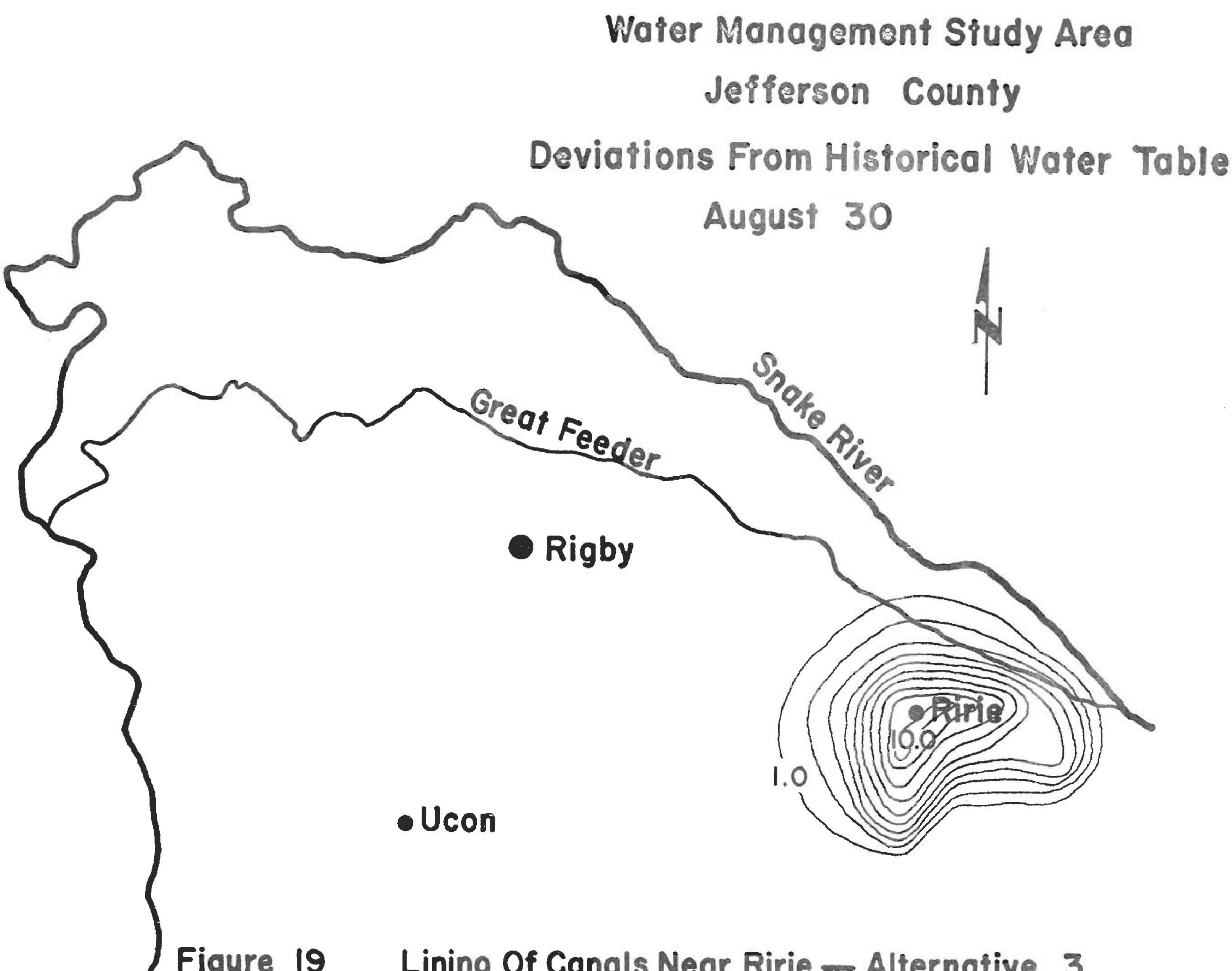



Figure 19 Lining Of Canals Near Ririe — Alternative 3

maximum water table elevations. As can be seen the maximum water table elsewhere in the study area is not affected by this management alternative.

Alternative 4 - Nine, 10 cfs wells near Rigby

The Lewisville-Rigby area is the primary area where the water table rises to within a few feet of the land surface causing problems to the residents. To achieve local relief several suggestions were made. One way to take excess water out of the system is to introduce a series of relief wells located on a straight line running west to east one mile north of Rigby. For this alternative 9 wells pumping 10 cfs each are located in Sections 12 of T 4N, R 37E, Sections 7-12 of T 4N, R 37E, and Sections 7 and 8 of T 4N, R 39E respectively.

In the immediate vicinity of the wells the maximum water table is effectively lowered between 5 and 7 feet. At one mile distance from the wells the water table is approximately 2.7 feet lower. No appreciable decline is observed in the area more than three miles away from the wells. Figure 20 is a contour plot of deviations from the historical maximum water table elevations. This alternative results in a 2.3 feet lowering of the maximum water table in the City of Rigby.

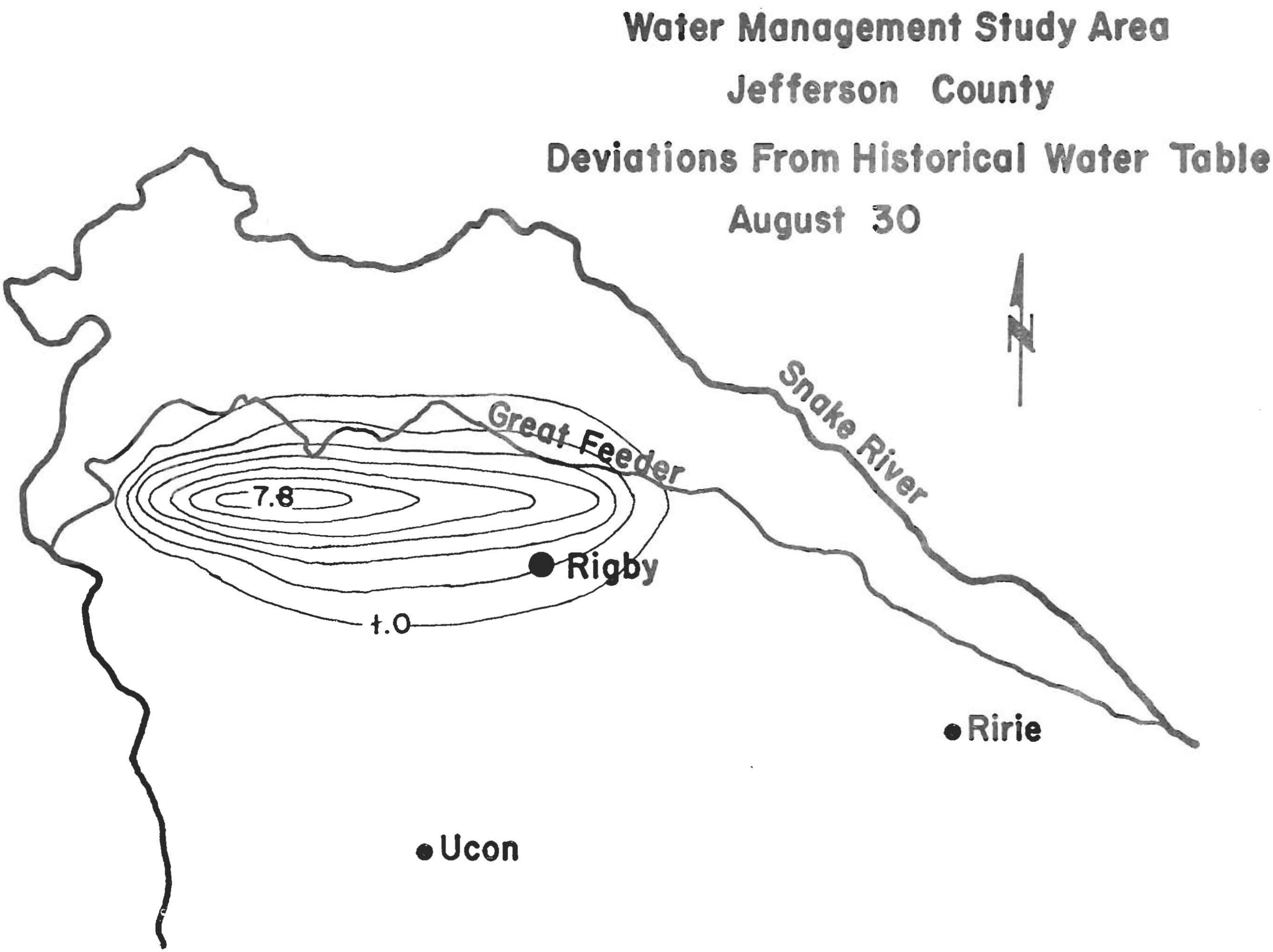



Figure 20 Nine 10 Cfs Wells East-West Of Rigby—Alternative 4

Alternatives 5 and 6 - Twenty and forty cfs wells near Rigby

Every year in the middle of the irrigation season a gravel pit situated 1 mile west of Rigby is filled by the rising groundwater table. To relieve the high water table problem in the City of Rigby, a 5 cfs capacity pump was installed at the site of the gravel pit. However, with this capacity no noticeable lowering of the water table in the gravel pit could be achieved. In order to determine the required capacities sufficient to obtain a noticeable drawdown, two alternatives were run involving the introduction of a 20 cfs and 40 cfs drainage well respectively.

The model run with the 20 cfs well shows an effective lowering of the water table of 7 ft. below the historical water table in the immediate vicinity of the well. One mile away from the well (Rigby) the water table is only 2 ft. lower than the historical maximum. A 40 cfs well lowers the water table effectively 14 feet below the historical maximum water table in the immediate vicinity of the well and 4 feet at the center of Rigby. These two runs confirm the additivity of the computed well drawdowns. Figure 21 is a contour plot of deviations from the historical maximum water table for the 40 cfs capacity well.

Alternative 7 - Four 10 cfs wells northeast of Rigby

Another possible method of lowering the water table at Rigby was considered which involves the installation of four drainage wells of 10 cfs

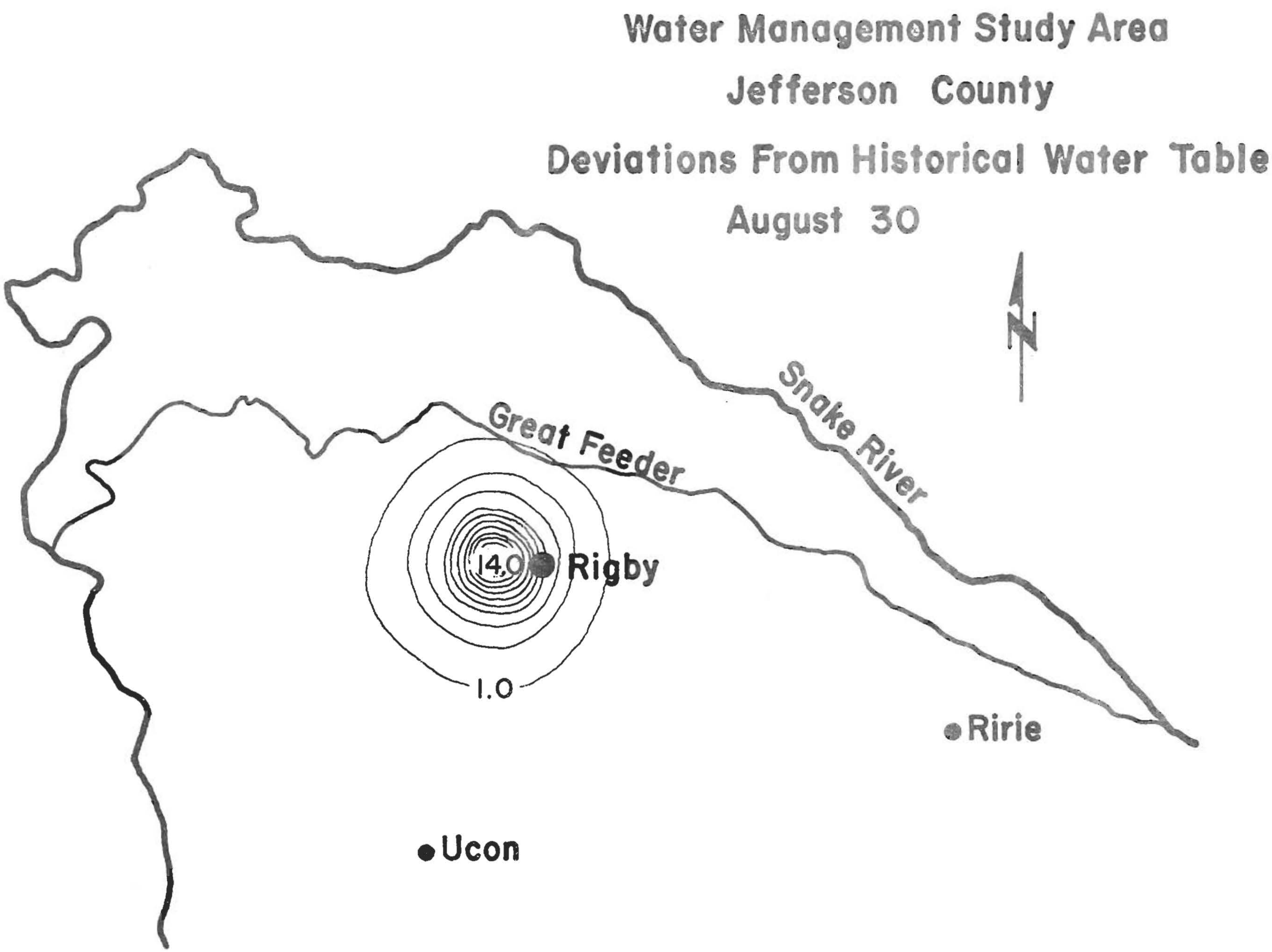



Figure 21. 40 Cfs Well Near Rigby — Alternative 6

capacity each located north and east of Rigby in the sections 7, 8, 17 and 20 of T 4N, R 39E.

Compared to the historical maximum water table, the water table at the well sites is effectively lower 5 feet. In Rigby the decrease is 3 feet. A contour plot of deviations from historical maximum water table elevations is shown in Figure 22. Except for the area around the City of Rigby the maximum water table elsewhere is not affected by this management alternative.

Alternative 8 - Lining the main stem of Burgess Canal

The Burgess Canal is a major irrigation canal that has its course through a large part of the area with high water table problems. Local residents think that the seepage from the Burgess Canal might be causing the water table problems. In fact, local government officials contemplated suing the Burgess Canal Company for causing the high water table problem.

Apart from legalities involved it is important to investigate this opinion. Alternative B suggests the lining of the main stem of the Burgess Canal while other canals remain unchanged. The lining of the Burgess represents an 11% reduction of total seepage from irrigation canals in the study area.

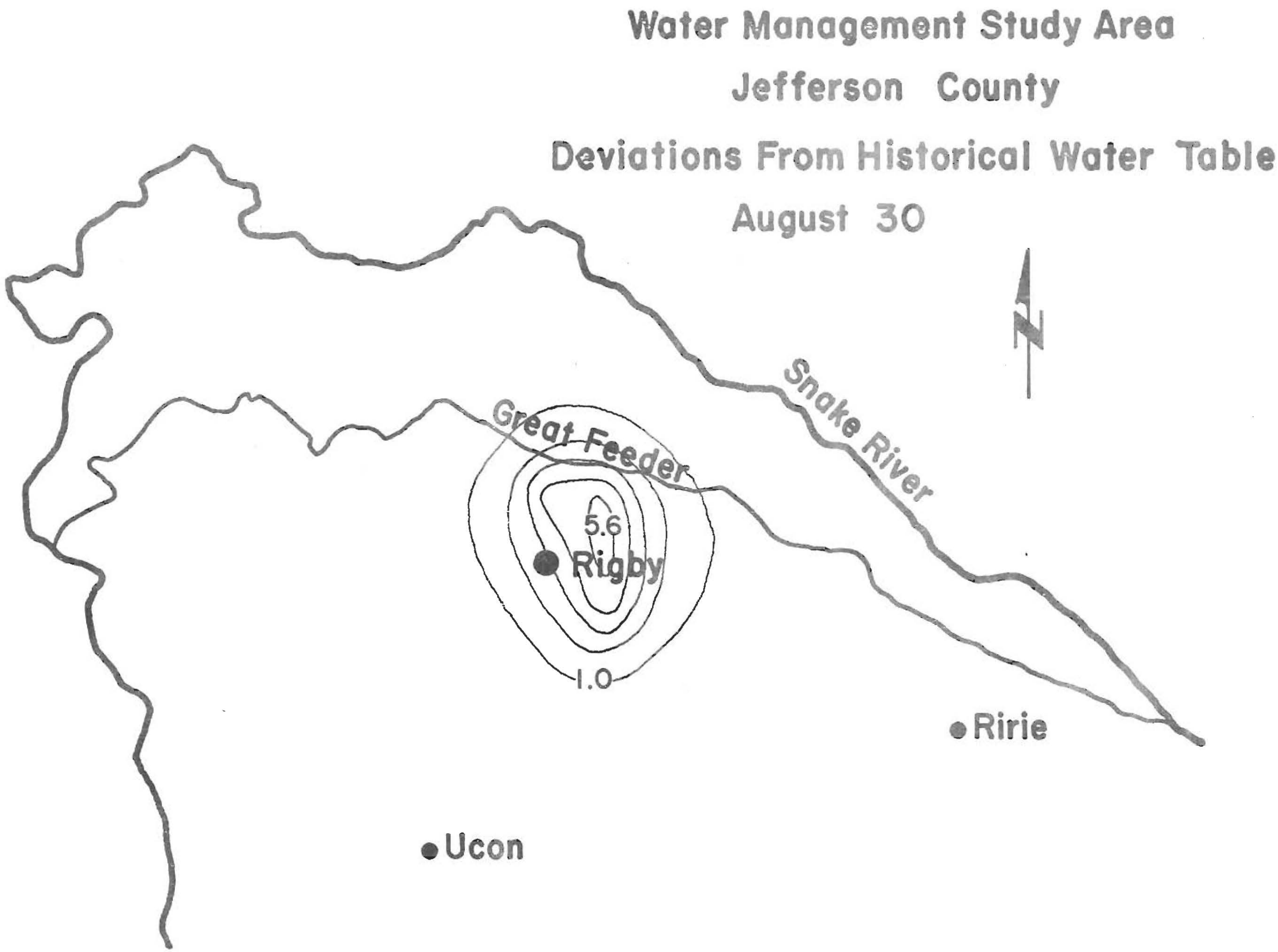



Figure 22 Four 10 Cfs Wells NE Of Rigby — Alternative 7

In the immediate location of the Burgess Canal, the water table maximum decreases 8 feet and in the area immediately surrounding the canal decreases range between 2 and 4. 5 feet. The City of Rigby, located less than one mile north of the Burgess Canal, shows a 4. 5 foot decrease in maximum water table elevation. Elsewhere no lowering of the maximum water table is observed. Figure 23 is a contour plot of deviations from historical maximum water table elevations resulting from lining the main stem of the Burgess Canal.

Alternative 9 -- Surface drain near Rigby

Another method of alleviating the high water table problem in the Rigby-Lewisville area may be the introduction of an open surface drain. Drains have been proposed for the area in the past and one land reclamation project using open drains has been constructed. Since this proposal is regarded by many as one of the feasible solutions, the model was run with a drain installed at a level approximately 4. 2 feet below the maximum water table elevation. The drain extends from Rigby 4 miles in a westerly direction.

The assumption is made that the drain is installed in the most efficient way so that the rising water table will intersect the drain over the whole length at approximately the same time. The drain operates as a constant head any time that the average water table elevation in the area is equal to or greater than the stipulated elevation of the drain.

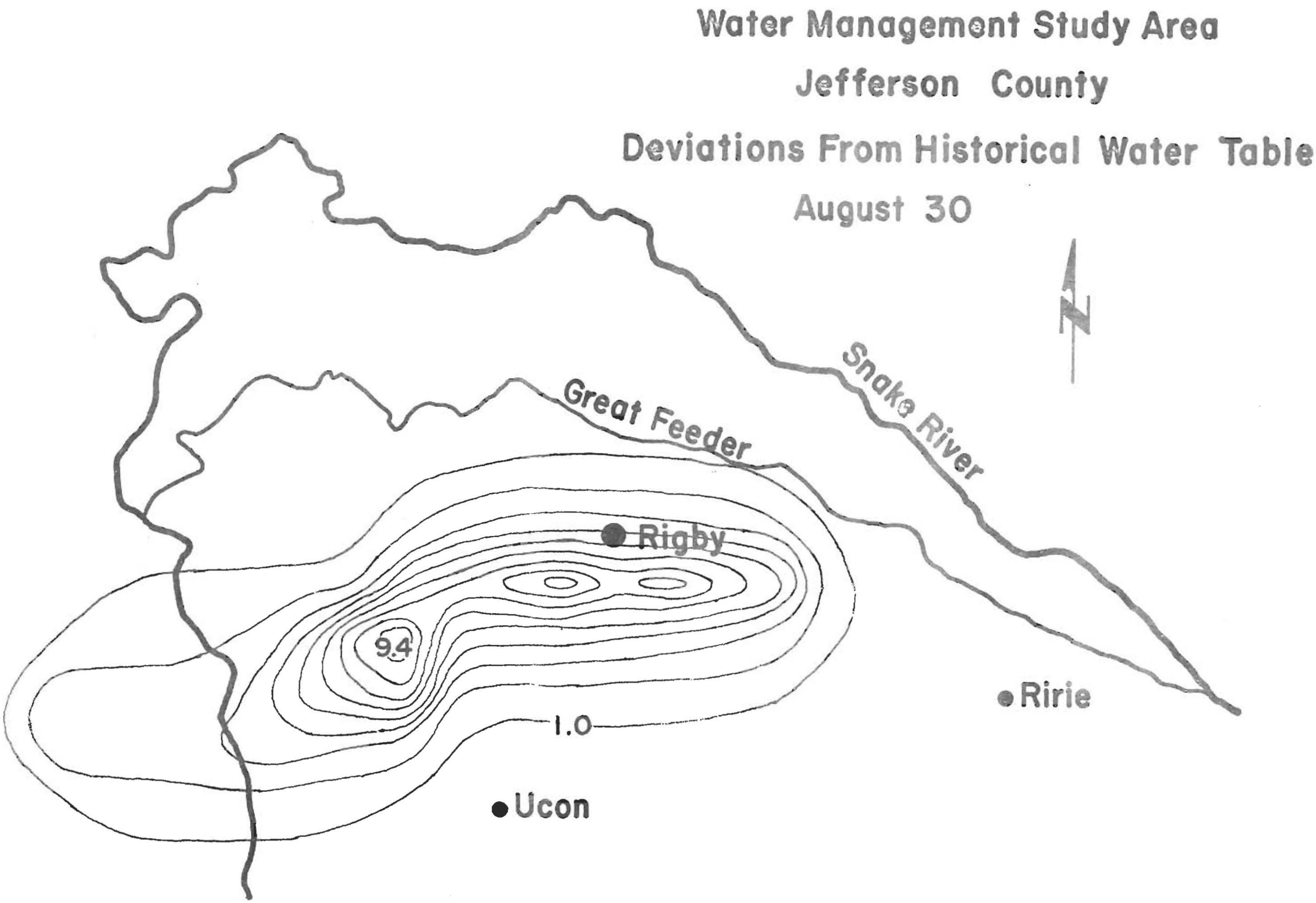



Figure 23 Lining Main Stem Of Burgess — Alternative 8

The model run at the location of the drain shows a lowering of the maximum water table of 4.2 feet average. At one mile distance from the drain the average decrease is 2.0 feet and at Rigby the drain results in a 3.1 foot lowering of the maximum water table. At a distance of 3 miles from the drain no lowering of the water table is observed. Deviations from historical maximum water table elevations as a result of the drain are shown in Figure 24. Figure 25 compares the hydrograph of a well at the drain site for the historical 1972 season with the water table levels calculated at the same location with the drain installed.

Alternative 10 - Thirty percent reduction in net diversions

The high water table problem is primarily caused by the excessive amount of water applied to the study area. Nearly all water applied originates as irrigation diversions from some 20 irrigation districts. The total net diversion (gross diversion minus return flow) amounted to an average of 13.8 acre feet per acre in 1972. Of that amount 6.1 acre feet was seepage from the irrigation canals. The net irrigation application is 7.7 acre feet per acre. This alternative involves a 30% reduction of the net diversions for all irrigation districts. Assuming that the seepage (6.1 feet) from the irrigation canals remains the same, the 30% reduction of the net diversion causes a 52% reduction of net irrigation application from 7.7 to 3.6 acre feet per acre.

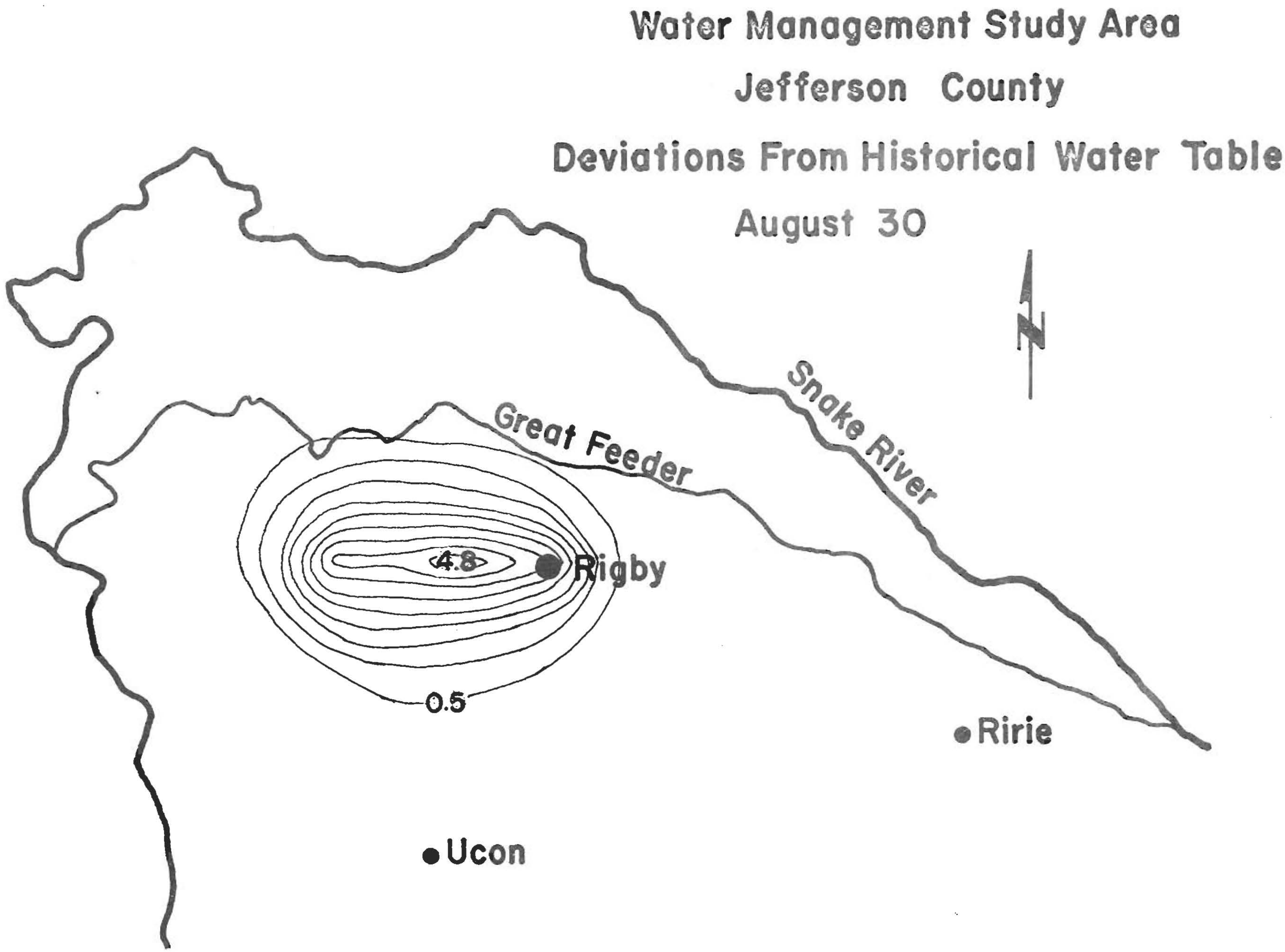



Figure 24 Drain East–West Of Rigby—Alternative 9

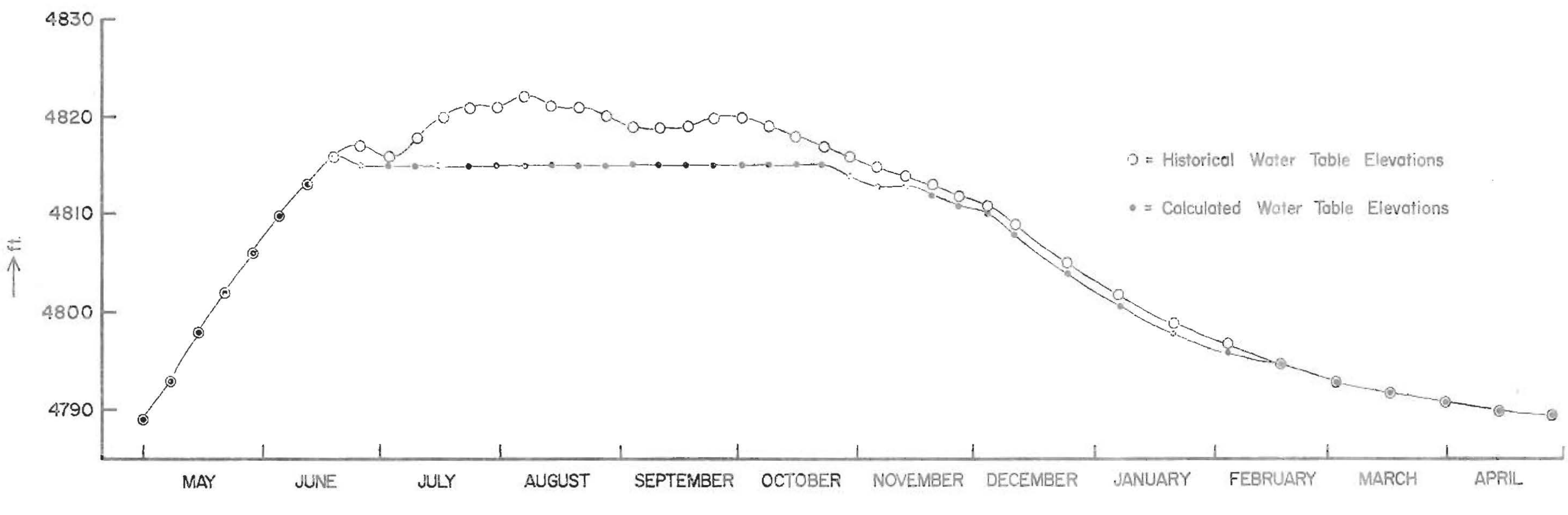



Figure 25. Water Levels At Surface Drain Site —— Alternative 3

A decisive decline of the maximum water table elevation over the entire area is observed. The water table north of the Great Feeder is 3 to 7 feet lower than the historical maximum. Around the City of Rigby the water table is 10 - 13 feet lower and near Ririe about 8 feet lower. Where the groundwater table connects with the regional groundwater table of the Snake River Plain a 9 to 12 foot decrease is observed. Figure 26 is a contour plot of deviations from historical maximum water table elevations. Figure 27 is a contour plot of deviations from the historical minimum water table as it occurs at the end of the simulation before the start of the new irrigation season (May 1). The calculated minimum water table is lower because with a 30% reduction in net diversions there is less recharge to the groundwater table. As was the case in management alternative 2, water levels at the end of the simulation intersects the historical recession curve at a lower level before rising again as a result of the irrigation in the next season.

Alternative 11 - Twenty percent reduction in net diversion

Whether a smaller reduction of net diversion would also yield satisfactory results was investigated in this management alternative which involves a 20% reduction in the net diversion, again assuming that the seepage losses remain the same. This results in a 35% reduction of net irrigation application from 7.7 to 5.2 acre feet per acre.

## Water Management Study Area
## Jefferson County

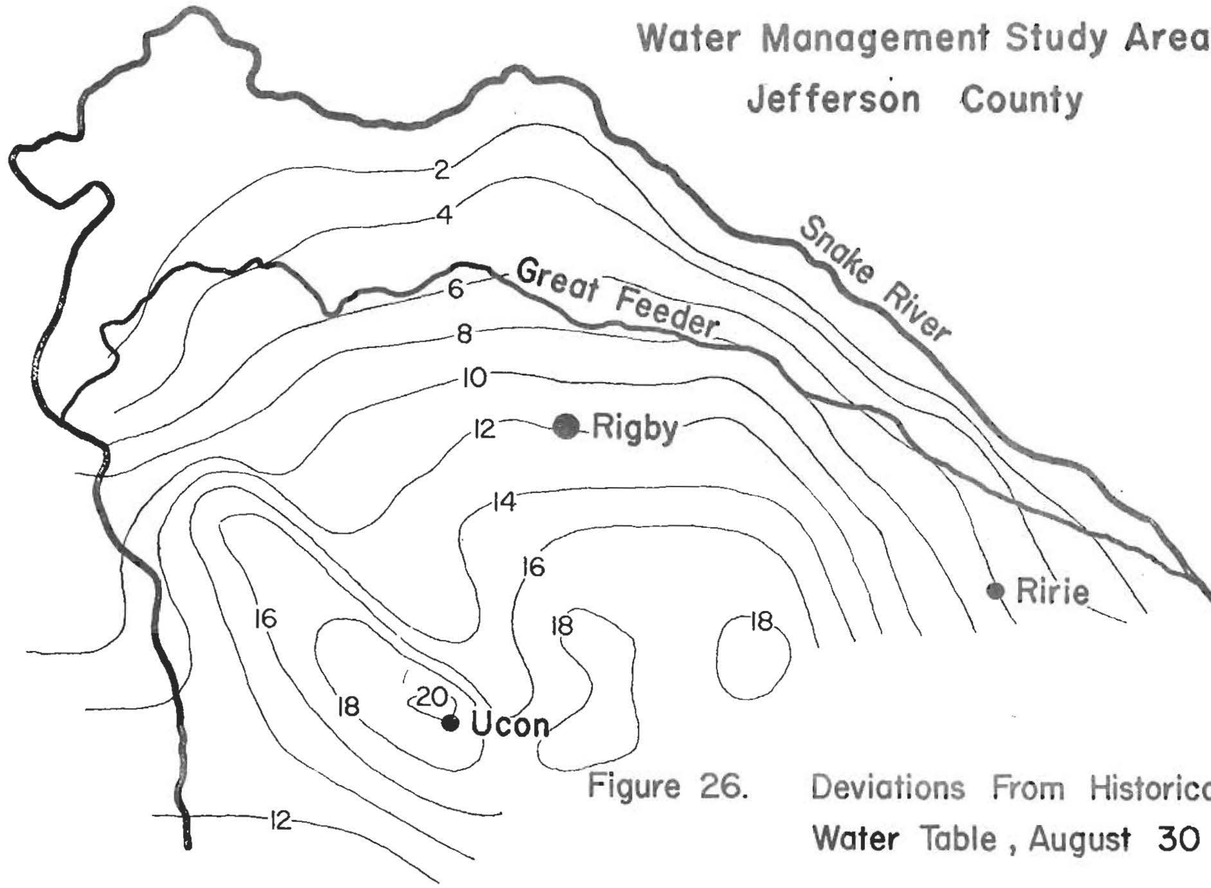



Figure 26. Deviations From Historical Water Table, August 30

30% Reduction In Net Diversion
Alternative 10

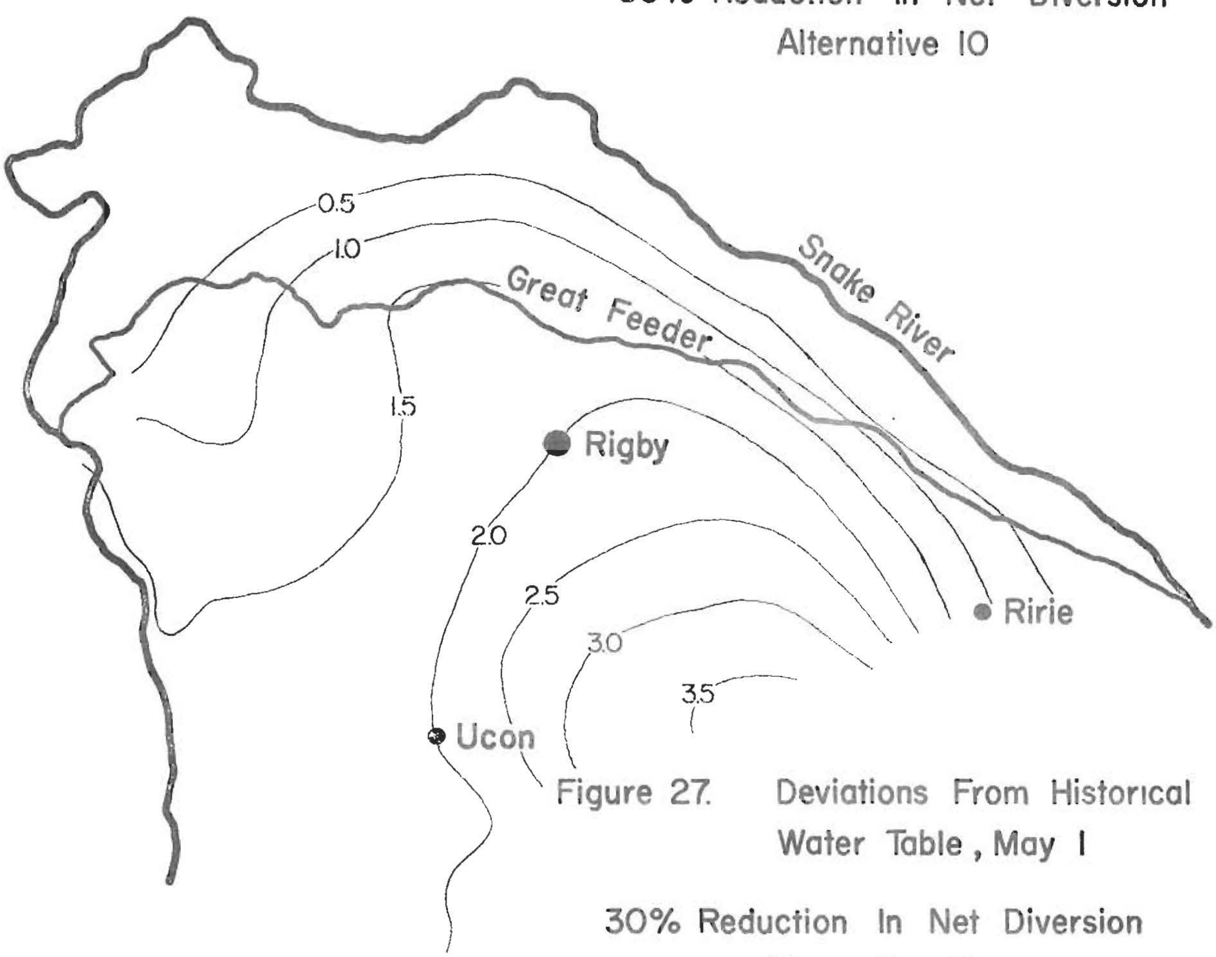



Figure 27. Deviations From Historical Water Table, May 1

30% Reduction In Net Diversion
Alternative 10

A considerable decline of the maximum water table over the entire area is evident. The area north of the Great Feeder averages a 2 to 5 ft. decrease from the maximum water table. Around the City of Rigby the maximum water table is 8 - 9 feet lower and near Ririe about 6 feet. Where the groundwater table connects with the regional groundwater table of the Snake River Plain, a lowering of the maximum water table between 6 and 8 feet occurs. Figure 28 is a contour plot of deviations from maximum historical water table elevations and shows clearly the overall lowering of the maximum water table. Figure 29 represents deviations from historical minimum water table and shows lower water table elevations as a result of the lower recession curve. The model was run for 5 consecutive years with a 20% reduction in net diversion to determine the effect of lower water tables at the beginning of each season on the maximum and minimum water table elevations. After 5 years the maximum water table declines to an equilibrium value which is less than one foot below the value at the end of one year. It then remains essentially in constant equilibrium with the reduced input to the aquifer.

Alternative 12 - Sprinkler Irrigation

Considering the general soil type and topography condition in the study area, the most efficient type of irrigation for the Snake River Fan is sprinkler irrigation. A simulation run was made in which the entire area is irrigated with sprinklers with a 70% efficiency factor. A closed delivery system is assumed so that conveyance losses are eliminated. The average

# Water Management Study Area
# Jefferson County

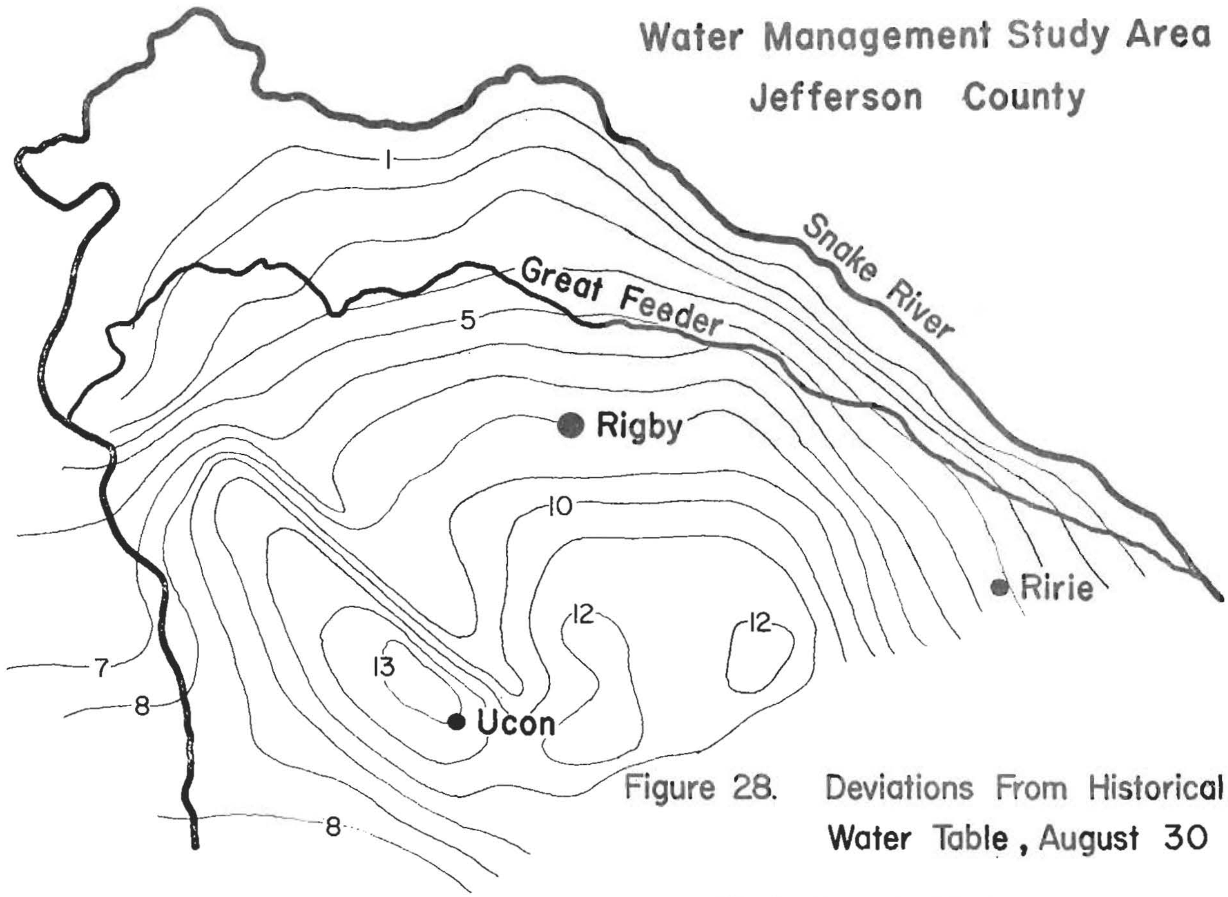



Figure 28. Deviations From Historical Water Table, August 30

20% Reduction In Net Diversion
Alternative II

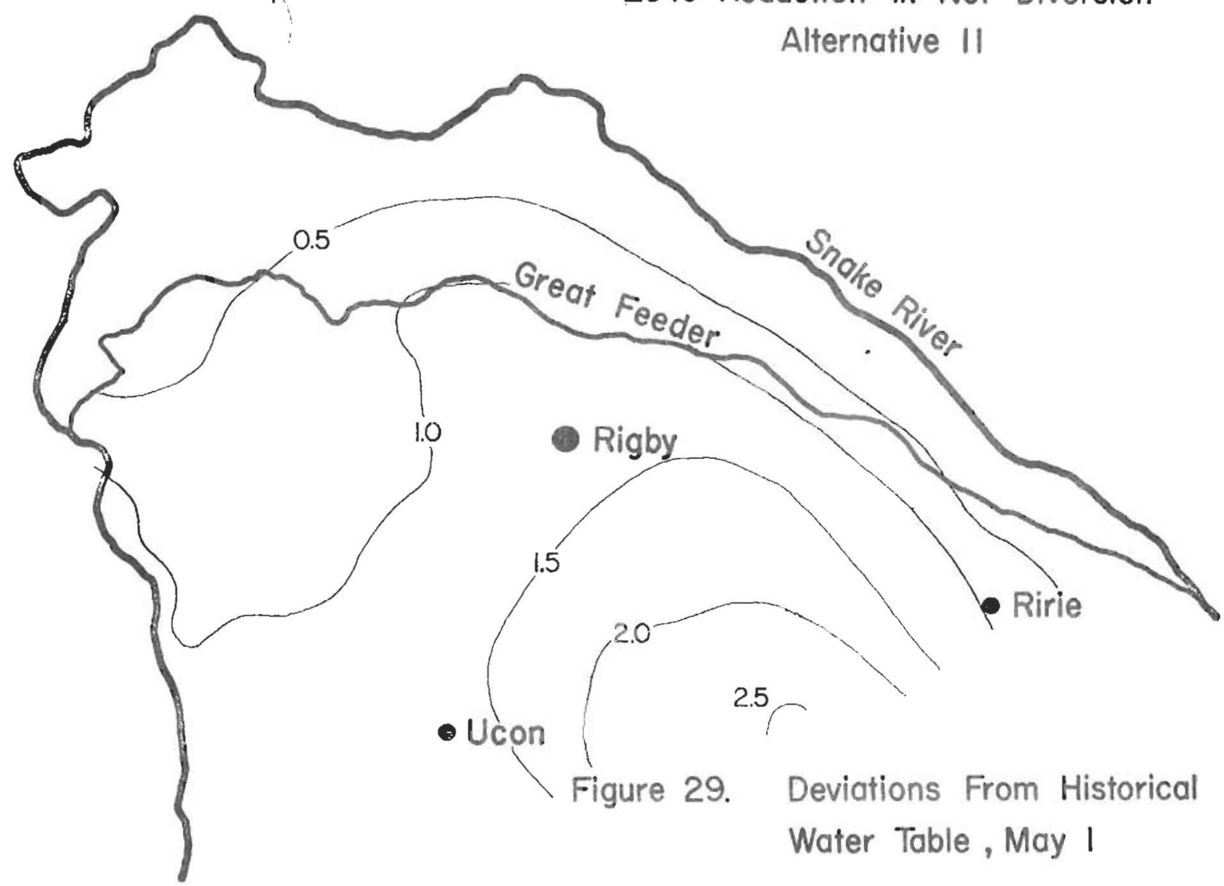



Figure 29. Deviations From Historical Water Table, May 1

20% Reduction In Net Diversion
Alternative II

crop evapotranspiration is 2.0 feet. With 70% efficiency only 0.85 acre feet per acre (including precipitation) is added to the groundwater aquifer via deep percolation instead of the present 11.8 acre feet per acre.

Historical water table rises of 35 to 40 feet are reduced to 3 to 5 feet respectively. Where the groundwater table connects with the regional groundwater table of the Snake River Plain, the maximum water table is 20 feet lower than the historical maximum.

The minimum water table at the end of a one year simulation is between 3 and 5 feet lower than the historical minimum water table. These levels approach the final value of the groundwater recession curve since minimal groundwater recharge exists with this management alternative. Figures 30 and 31 are contour plots of deviations from the maximum and minimum historical water table elevations respectively.

## Alternative 13 - Long term recession curve

Under the existing water management procedures on the Snake River Fan, the minimum water table level occurs just before the beginning of the irrigation season about May 1st. There are numerous shallow domestic wells in the area. Some concern exists that these wells will run dry if the groundwater table is not recharged annually by the deep percolation of irrigation water. Without this recharge the water levels in the fan are expected to follow a depletion curve until a steady state is reached in which

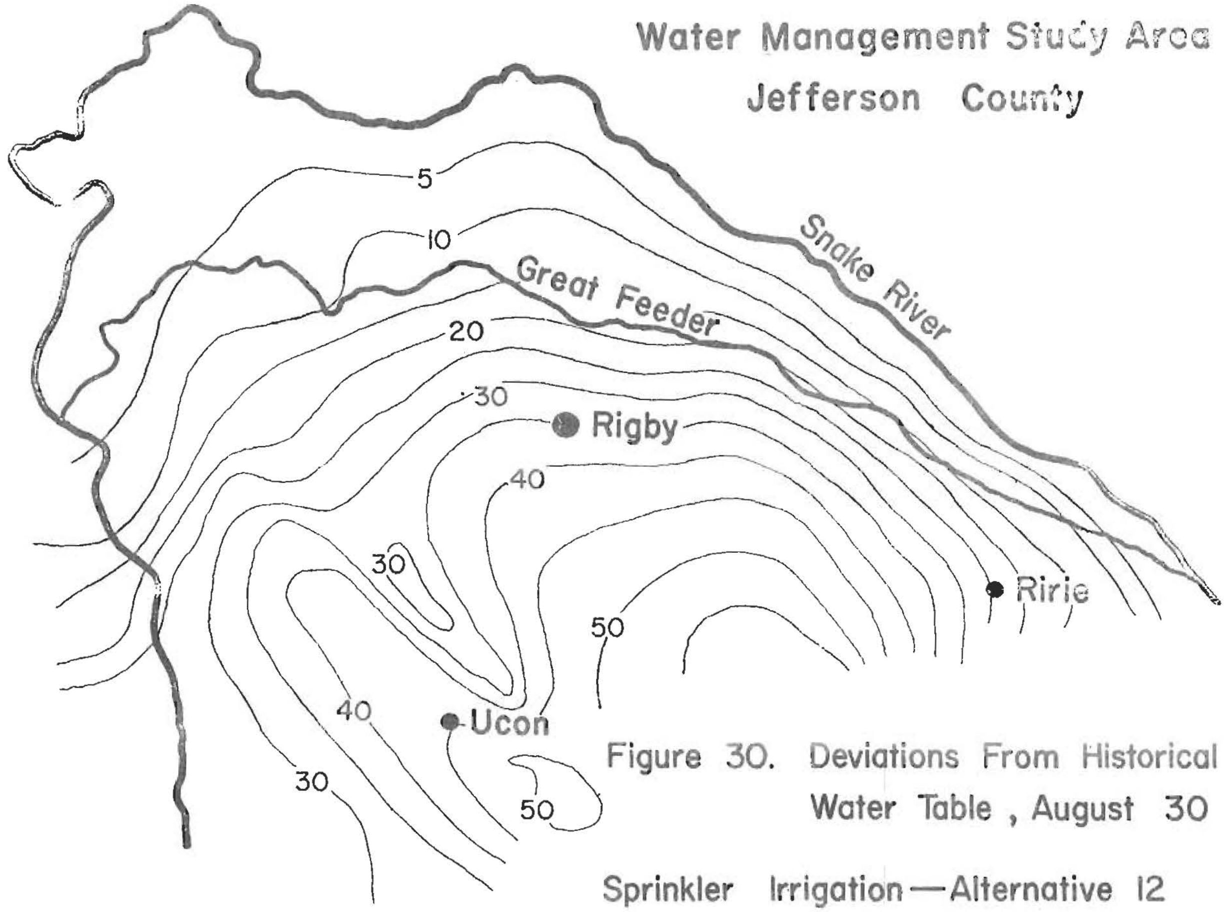



Figure 30. Deviations From Historical Water Table, August 30

Sprinkler Irrigation—Alternative 12

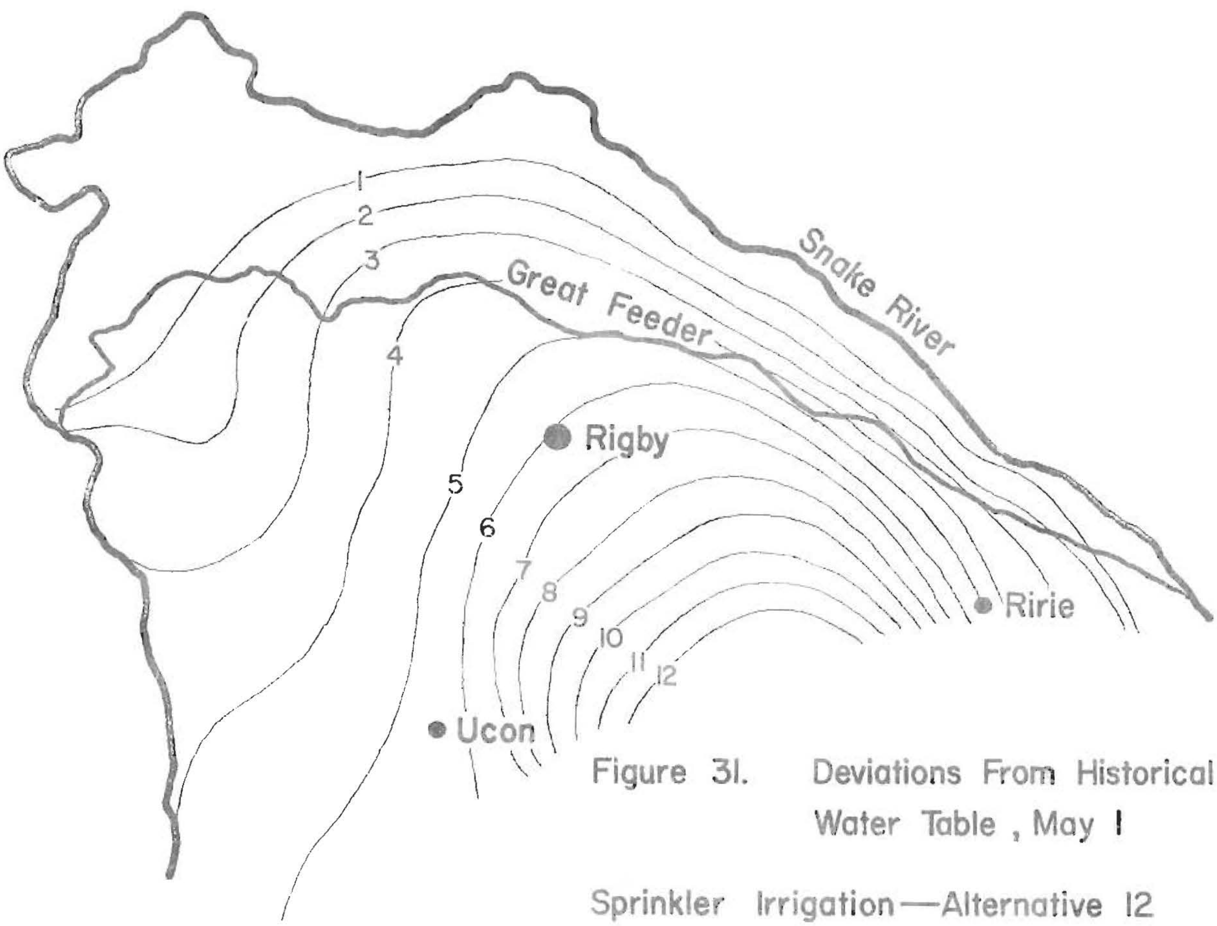



Figure 31. Deviations From Historical Water Table, May 1

Sprinkler Irrigation—Alternative 12

the inflow from the Snake River, Great Feeder and some valley subsurface flow equals the flow out of the area to the regional groundwater table of the Snake River Plain. To determine the depletion curve and the equilibrium water table of the Snake River Fan, a simulation run was made in which after one season the only input to the area is seepage from the Snake River and the Great Feeder Canal.

The equilibrium water table is reached at a level averaging 5 feet below the historical minimum in the area around Rigby and 5 to 6 feet in the area north of the Great Feeder. In the vicinity of Ririe the minimum water table is 5 feet lower and where the local water table connects with the regional groundwater table of the Snake River Plain, the levels are 6 to 7 feet lower. Since this boundary with the Snake River Plain aquifer is influenced not only by the flow regime in the study area, but also, in a lesser degree, the minimum calculated water table my be conservative by regional groundwater levels.

Figure 32 shows behavior of a representative well in the study area for the 1972 season and the computed recession curve and equilibrium water level resulting from a cessation of irrigation after one year.

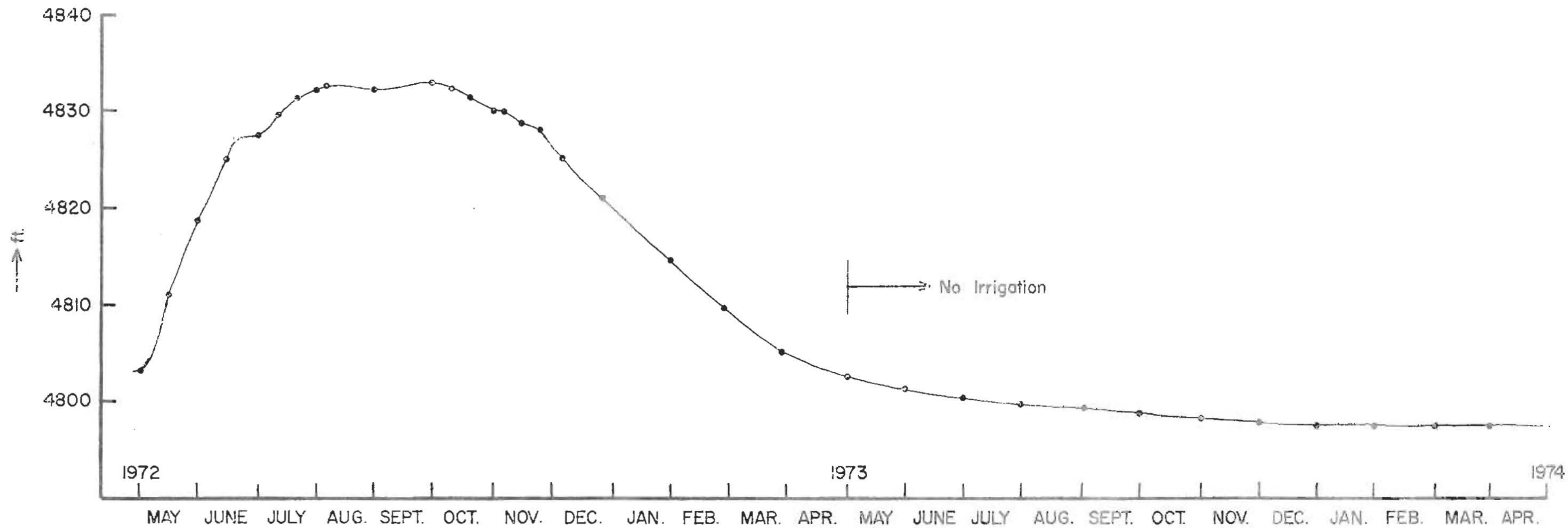



Figure 32. Simulated Seasonal Water Table And Recession Curve — Jay Clark Well

## DISCUSSION AND CONCLUSIONS

High water table or sub-water conditions in the Rigby-Ririe area of the Snake River Fan are caused by excessive input to the gravel aquifer. The major sources of the input are irrigation application, canal seepage losses and Snake River losses. Irrigation diversions to the area are increasing about 0.2 af/acre/year and averaged 13.1 af/acre for the 1972 May through September irrigation season as reported in Water District 1 records and 17.0 af/irrigated acre as measured over the May-November period. With this trend, high water tables have been and are continuing to become progressively worse. Damage to rural and urban lands is significant as indicated by a mail survey in which damages in excess of $25,000 per year were reported. Irrigation diversions are higher than average for Idaho and transmission losses for the dense network of canals and the Great Feeder Canal approach 40 percent of the gross diversion and contributes 49 percent of the input to the aquifer. Above average farm applications and the absence of natural or artificial surface drainage facilities makes almost all of the excess of farm application over evapotranspiration effective in recharging the aquifer. High infiltration rates necessitate large farm stream sizes; however, long run lengths and uneven leveling of borders contribute to uneven water distribution and decreased irrigation efficiency.

The digital model developed to study the effects of water management changes on the aquifer accurately predicts seasonal aquifer response. The calibration routine is effective in systematically adjusting geohydrologic parameters to fit historical water table responses and is especially useful where geohydrologic data is lacking. Verification of the model using 1972 data provided a simulation of the maximum water table rise over the aquifer with a standard deviation of 1.25 ft. This is considered more than sufficient for planning purposes and could not have been achieved using trial and error calibration procedures. Operation of the model has proved very flexible in evaluating aquifer response to changes in water management.

Results of the management studies on the aquifer indicate that reasonable changes in management of the Snake River to decrease the river stage would not appreciably affect the maximum use of the aquifer and would not remedy the high water table problem in the Rigby area. Elimination of transmission losses by lining of all canals would reduce the maximum water table rise. Local relief may also be achieved by well or well field operation; however, the quantities which must be pumped to achieve significant lowering of the water table are large and operation may not be economically feasible. Construction of an open drain near Rigby as has been proposed by local residents could lower the water table at Rigby by as much as 3 feet. Any drain constructed would necessarily be large because of the gravelly substrata and depth required to achieve significant lowering of the water table. It is estimated that to achieve the 3 foot reduction in water table height at Rigby that a 100 cfs drain would be required with an invert depth of 12 to 14 feet below ground surface.

The use of well and drains to remove water from the aquifer to alleviate the high water table problem are treatments of the symptoms and not the main causes of the problem. The most feasible solution is to reduce inputs to the aquifer - namely deep percolation from irrigation and canal losses.

A 20% reduction of the net irrigation diversion to the area would correct the high water table problem in both the Rigby and Ririe areas. Implementation of this reduction could be achieved either by system consolidation to reduce canal seepage, canal lining of specific reaches of canals or decreasing on farm water use. Those parts of the area with shallow soils and high infiltration rates are most amenable to sprinkler irrigation and conversion to closed system sprinkler irrigation for all or part of the area would solve the high water table problem. Minimum water table elevations under any alternative studied are not sufficiently decreased to jeopardize domestic well water supplies. The long term recession curve with zero input from irrigation indicates a lowering of the minimum water table of only 5 to 6 feet.

Implementation of any alternative to alleviate the high water table problem in the study area will depend on the willingness of residents to cooperatively undertake a program and on the repayment capacity of the community to finance any venture. Further studies underway by the University will evaluate these factors and determine costs on alternative water management programs.

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