Research Technical Completion Report

Project B-041-IDA

ANALYZING AND PREDICTING IRRIGATION DIVERSIONS IN SOUTHEASTERN IDAHO

by

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Agricultural Engineering

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ANALYZING AND PREDICTING IRRIGATION DIVERSIONS
IN SOUTHEASTERN IDAHO

ABSTRACT

by Sung Kim, M.S.
University of Idaho, 1981

A study was done to analyze the daily water flow data from two large irrigation districts located in the Upper Snake River region of southeastern Idaho and to develop a methodology for predicting daily water diversions. Data collected during the 1978, 1979, and 1980 irrigation seasons were used for this study.

Crop consumptive water use was estimated by the combination method on a daily basis. Crop consumptive use estimates varied greatly on a daily basis, and the patterns were quite different from year to year.

Seasonal irrigation water use amounts were different for different years for the different districts, but the seasonal water use patterns were similar for different years and districts.

Graphical and statistical methods were used to determine fluctuations and relations among inflow, outflow, evapotranspiration, and precipitation. A slight change of evapotranspiration resulted in a rather large change of inflow. A weekly cycle was found to exist within outflows, but no significant frequency was found within inflows.

Relationships between time and diversion requirements were established. Based on the time effects, proper consumptive irrigation requirements were estimated at the district level.

A computer program was developed for predicting water diversions for the study area and did a reasonable job.

CHAPTER 1

INTRODUCTION AND OBJECTIVES

Introduction

Economic and social development depends on increased agricultural production. Increased production can be brought about by creating additional lands through new irrigation projects or improving present irrigation systems and practices for efficient water use and continued productivity.

Any successful irrigation project depends upon a suitable water supply for crop requirements. There must be enough volume to supply the seasonal requirement and ample flow rates to meet the peak use demand. It is necessary to calculate the consumptive use of the crops in an area as a first step in determining irrigation water requirements. In addition to consumptive use, a certain amount of water should be allocated for losses in administration, conveyance, and application. At the same time additional water may be needed to maintain a favorable salt balance.

A farm operator may be able to control the delivery of water to his farm if he has control of the diversion. For example, he can manage the timing and quantity of direct water supply from a well or a stream. In this case only the water source or the water rights can limit both the timing and amount diverted for use. However, most water is delivered to farms through a supply system operated by a water user association or irrigation district. The management of an irrigation district must consider many factors in determining the proper diversion requirements. If too little is diverted, irrigators' needs are not met; and if too much is diverted, water is wasted.

As efficient irrigation saves water and energy, there have been many studies with the objective of improving various aspects of irrigation systems such as supply, distribution, and application of water. The studies have dealt with both irrigation system design and irrigation water management.

Mathematical models and procedures have been developed to assist in system design and water management. It is also noted that the overwhelming majority of these procedures are intended for use at the individual farm or field level. Only limited emphasis has been directed to analysis of irrigation water use at the district level. Most system analyses of irrigation districts have been previously conducted, but not necessarily for the primary purpose of determining diversion requirements (Brown et al., 1974; Carter et al., 1971; Brockway et al., 1973; Claiborn, 1975). A program has been developed by Buchheim and Brower (1981) to forecast water diversions to meet irrigation requirements.

The irrigation models and procedures developed for on-farm systems consider and predict the dynamic variations in the systems on a short-term basis. On the other hand, most of the systems analyses of irrigation districts have considered variations only on a long-term basis which ranges from two weeks to an entire season.

For efficient operation of an irrigation district, short-term variations in water use need to be considered. It would be beneficial to use dynamic procedures to consider daily variations in diversions as related to water use in district irrigation systems. Even though it might be impossible to match demand and supply exactly, a daily-based analysis would contribute to more efficient irrigation on a project-wide basis.

Objectives

The objectives of this study were to analyze the dynamic variations between inflow and outflow on a daily basis for two irrigation districts and to develop a daily diversion prediction model for the irrigation districts. Specific objectives were

1. To determine factors which influence the diversion inflow and outflow from a district. These factors include evapotranspiration, canal seepage, on-farm deep percolation, irrigation period, and lag times within the system.

2. To develop a model for predicting diversion requirements on a daily basis for the irrigation districts and apply the model to the study area.

CHAPTER 2

LITERATURE REVIEW

Farm Water Delivery Administration Organizations

Most irrigation water in the western United States is delivered to farms through a supply system operated by a water-user organization. Accordingly, it is necessary to understand water-user organizations. The following organizations are classified by Riebol (1967):

1. Mutual irrigation companies.
2. Commercial companies.
3. Irrigation districts.
4. Water conservancy districts.

An understanding of the delivery policy by any of the organizations is needed to determine the actual operations of the delivery systems of an irrigation project. This delivery policy is called a scheduling system or schedule. Districts or associations select the schedule after considering the legal, physical, and economic factors along with the resulting apportionment of the costs of the water supply, distribution, and application systems. Schedule types may be broadly classified as demand, rotation, or continuous flow. Combinations of two or more of these methods may be used in any system depending on the location of the farm with respect to the distribution system, the seasonal water requirements, and the available water supply. An alternate classification is to broadly group the schedule types into either rigid (predetermined) schedules or flexible (modifiable) schedules. If the flow duration is variable, further combinations can be defined. Schedule types are classified as follows by Replogle et al. (1980): Rigid scheduled may be (1) fixed amount-fixed frequency, (2) fixed amount-variable frequency, or (3) varied amount-fixed frequency. Flexible schedules may be (1) demand, (2) frequency demand (24-hour duration), or (3) limited rate demand.

The fixed amount-fixed frequency delivery schedule is generally the least desirable from the user's viewpoint. The other two rigid schedules can, theoretically, be optimized for a specific crop on specific soil and field conditions. However, uniform conditions are unlikely to exist for much of the service area. On a project or district basis, rigid schedules often result in low project irrigation efficiencies, drainage problems, leaching of soil nutrients, and wasted labor on the farm. All of these rigid schedules are frequently modified by using reservoirs either on-farm or at the district level to provide a modified flexible schedule.

The limited rate demand schedule is a flexible schedule that is highly practical for the water user. It enables the user to irrigate each crop, usually when needed, and to use a stream size that is economical and efficient for the particular situation. Thus, differences in soils and crop requirements can normally be accommodated. An irrigation project employee--usually a ditch rider--may need to be on call 24 hours a day to reduce operational spillage as the farmer changes his flow rate or finishes irrigating. This need does not occur when the system has an automated canal or closed or semiclosed pipelines for delivery coupled with suitable reservoirs.

Replogle et al. (1980) have reported that nearly all large projects in the northwestern United States operate on a type of limited rate demand schedule. They report that in some cases it is possible to deliver water on a straight demand schedule during part of the season and change to one of the modified demand systems or even to a rigid schedule during peak crop water requirement periods.

Further details about delivery policy can be found in Riebol et al. (1967) or Replogle et al. (1980).

Irrigation Efficiencies

A considerable amount of research has been devoted to the subject of irrigation efficiency, and many types of analyses have been used to compute the efficiency of a particular phase of an irrigation operation.

The following irrigation efficiency terminology is selected from that adopted by the On-Farm Irrigation Committee of the Irrigation and Drainage Division of the American Society of Civil Engineers (1978).

1. Irrigation Efficiency, IE, is the ratio of average depth of water which is used beneficially to the depth of applied water. Beneficially used water is that which is used to satisfy soil moisture demands, leaching requirements, environmental control, and pesticide and fertilizer application or management water.

2. Application Efficiency, AE, is the ratio of average depth of water stored in the plant root zone to the average depth of applied water by an irrigation application subsystem. AE does not give any indication of under- or overirrigation at any part in the farm.

3. Water Conveyance Efficiency, CE, is the ratio of the volume of water delivered to the point of use by an open or closed conveyance system to the volume of water introduced into the conveyance system at the supply source or sources.

4. Unit Irrigation Efficiency, UE, is the ratio of the volume of irrigation water required for beneficial use in a specified irrigation area to the volume of water delivered to the area.

5. Reservoir Storage Efficiency, SE, is the ratio of the volume of water available from the reservoir for irrigation to the volume of water delivered to the storage reservoir--surface or underground--for irrigation.

6. Farm Irrigation Efficiency, FE, is the product of the component terms expressed as ratios:

   $$FE = SE \cdot CE \cdot UE$$

   The overall irrigation efficiency for a project or a river basin can be expressed in a similar manner.

Additional discussions and definitions of irrigation efficiency terms can be found in articles by Burman et al. (1980).

Irrigation Water Requirements

The designer or operator of an irrigated system must determine irrigation water requirements, R, for both short periods and on a seasonal basis. The units of R usually are volume per unit area or depth. The irrigation water requirement is defined by Doorenbos and Pruitt (1977) as

> the depth of water needed to meet the water loss through evapotranspiration, ET, of a disease-free crop growing in a large field under nonrestricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment

The requirement R also can be stated as:

$$R = ET - Pe + (\text{other beneficial uses}) \quad (2\text{-}1)$$

where

ET = evapotranspiration

Pe = effective precipitation

Other beneficial uses include germination of seeds, climate modification, freeze protection, fertilizer application, depression of soil temperature, and dust suppression.

Burman et al. (1980) have presented a flow chart outlining the sequential steps for estimating irrigation water requirements from climatic data (Fig. 2-1).

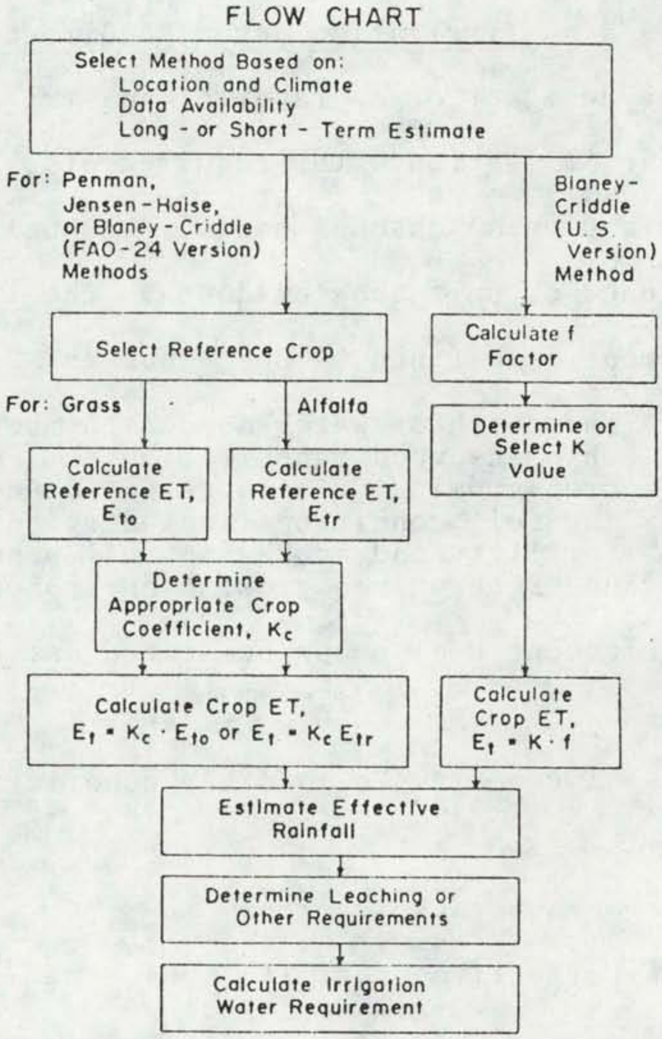

Fig. 2-1.--Typical flow chart for estimation of irrigation water requirements from climatic data (from Burman et al., 1980, p. 194)

The term evapotranspiration may have different meanings in various parts of the world and even in the same country. The following definitions are given by Burman et al. (1980).

> Evapotranspiration, ET, is the combined process by which water is transferred from the earth's surface to the atmosphere. It includes evaporation of liquid or solid water from soil and plant surfaces plus transpiration of liquid water through plant tissues expressed as the latent heat transfer per unit area or its equivalent depth of water per unit area.

> Potential evapotranspiration, PET, is the rate at which water, if available, would be removed from the soil and plant surface expressed as the latent heat transfer per unit area or its equivalent depth of water per unit area.

Crop Versus Potential ET

The relationship between the ET of a specific crop (ET) at a specific time in its growth stage and potential ET (PET) is of practical interest to the designer or operator of an irrigation system. The relationship has led to crop coefficients:

$$K_c = \frac{ET}{PET} \qquad (2\text{-}2)$$

where K_c is referred to as a crop coefficient which incorporates the effects of crop growth stage, crop density, and other cultural factors affecting ET.

Reference Crop Evapotranspiration

Because of the ambiguities of potential evapotranspiration, reference crop evapotranspiration, E_{to} or E_{tr}, is frequently used. Doorenbos and Pruitt (1977) use E_{to} to replace potential evapotranspiration as "the rate of evapotranspiration from an extensive surface of 8 to 15 cm, green grass cover of uniform height, actively growing, completely shading the ground, and not short of water."

An alternate definition, E_{tr}, widely used in the western United States, is presented by Jensen et al. (1974). E_{tr} represents:

> The upper limit or maximum evapotranspiration that occurs under given climate conditions with a field having a well-watered agricultural crop with an aerodynamically rough surface, such as alfalfa with 12 inches to 18 inches of top growth.

Actual ET is estimated using the following equation:

$$ET = K_c \cdot E_{tr} \quad \text{or} \quad ET = K_c \cdot E_{to} \qquad (2\text{-}3)$$

Determining Evapotranspiration

Evapotranspiration can be measured in the field or estimated from climatological and crop data. Direct field measurements are very expensive and are mainly used to provide data for calibrating method used to estimate ET using climatic data.

Lysimeters (evapotranspirimeters) provide a direct measurement of ET. By this method evapotranspiration can be determined accurately over periods as short as one hour. A detailed summary of the use of lysimeters for evapotranspiration can be found in an article by Harrold (1966) and in World Meteorological Organization (1966) Technical Note No. 83.

Numerous methods have been developed to estimate ET (Jensen, 1974; Doorenbos, 1977; Penman, 1967; Thornthwaite, 1948; Blaney and Criddle, 1962). Some of the estimating equations are very simple and require relatively little data, but they must be calibrated or tested for any new area. Other equations are very comprehensive and require considerable amounts of data.

Water Balance in an Irrigation District

Irrigation systems analysis involves the quantification of all water entering and leaving an irrigation area in terms of a water balance equation. Irrigation studies based upon the application of a water balance or water budget type analysis have been conducted. The majority of these investigations have been carried out primarily to research water quality characteristics or water-use efficiencies.

Brown et al. (1974) and Carter et al. (1971) have carried out water balance studies for several consecutive irrigation seasons on two large irrigation projects in southern Idaho. Their work has been aimed at collecting water quality and sedimentation output data in addition to some actual water-use pattern data.

Claiborn (1975) evaluated irrigation efficiencies in the Upper Snake River region of Idaho. He investigated water use on six irrigation districts during the 1974 irrigation season. He derived deep percolation losses and irrigation efficiencies by using an inflow-outflow water balance analysis. The project irrigation efficiencies ranged from 10 to 42 percent.

Worstell (1978) evaluated irrigation efficiencies during a water-short year, 1977, and a year when water was not short, 1976, for two irrigation projects in Idaho. He also determined statistical relationships between the project irrigation efficiencies of both systems for each of the two years and between both years for each system. Average seasonal irrigation efficiencies of the two irrigation districts were 18 and 54 percent in 1976, and 16 and 43 in 1977. There were no significant differences between the irrigation efficiencies measured in the two different years.

Kharchenko and Katz (1970) developed methods for establishing a water balance on irrigated land in the USSR. They divided irrigated territories into areas where underground runoff is prevailing in water balance expenditure elements and where underground runoff is practically absent.

Tseitlin and Pol'skii (1976) investigated the water balance of channels used intensely for irrigated lands in the USSR. In this study, the complex process of water and moisture exchange which occur directly from irrigated lands are eliminated from consideration. The inflow of water into the river channel and consumption of water from the channel within the investigated reach are compared in the channel balance.

Buchheim and Brower (1981) developed a computer program to forecast water diversions to meet irrigation requirements on a daily basis. They integrated on-farm scheduling with system management referred to as system scheduling. However, their study did not involve consideration of time-dependent relationships within an irrigation district.

Fleming (1975) stated that a water balance is a time-dependent relationship which must be computed as a continuous function in order to fully understand catchment response. However, previous studies dealing with irrigation districts have been carried out without considering time-dependent relationships. Owing to the difficulties of measuring or estimating variations during short time periods, those studies have been based on long time periods, ranging from two weeks to one year.

Time Series

A set of observations arranged chronologically is called a time series. Time series have been observed in connection with quite diverse phenomena and a wide variety of researchers. There may be several possible objectives in analyzing a time series. These objectives may be classified as description, explanation, prediction, and control.

Numerous studies have utilized time series in different applications. A review of time series literature can be found in articles by Chatfield (1975). Box and Jenkins (1970) have made an important contribution by describing the approach to time series analysis, forecasting, and control.

Yevjevich (1972) applied time series to hydrologic processes. He classified hydrologic data into four types according to the practice of measurement and reporting of data. The four types are (1) historical data recorded in time, (2) field data recorded in space, (3) empirical data recorded in time or space or both, and (4) concurrently measured data on two or more variables recorded in time or space or both.

When successive observations are dependent, future values may be predicted from past observations. If a time series can be predicted exactly, it is said to be deterministic. However, most time series are stochastic in that the future is only partially affected by past values (Chatfield, 1975).

According to Unny et al. (1981), hydrologic time series and in particular stream flow time series are described depending on the time interval between successive observations as daily, monthly, or yearly time series. The properties of daily stream flow time series are different from yearly and monthly time series in the sense that these time series are described by the presence of rapid ascension to peaks and exponential recession. The nature of daily time series is influenced by the cause and effect relationship in the rainfall-runoff process in short intervals of time. Thus, a proper model for daily stream flow time series should consider the deterministic transfer relation between rainfall and streamflow.

Though irrigation processes within an irrigation district have a similar cause and effect relationship as within a watershed, time series analysis applied to irrigation process is not found in the literature.

Correlation

Linear Correlation

A correlation coefficient (r) is a measure of the linear association between two variables. Values for correlation coefficient are dimensionless and range between -1 and +1. If r is -1 or +1, the variables have a perfect linear relationship. A negative value for r indicates that as one variable increases, the other decreases. A positive value of r indicates that as one variable increases, the other also increases. If r is 0, there is no linear association between the variables (Ott, 1977).

Autocorrelation

The investigation of the sequential properties of a series by autocorrelation analysis is now considered a classical statistical technique. It is used to determine the linear dependence among the successive values of a series that is a given lag apart (Yevjevich, 1972).

The autocorrelation coefficient, r_k, is

$$r_k = \frac{\text{Cov}\ (X_i,\ X_{i+k})}{(\text{Var}\ X_i \cdot \text{Var}\ X_{i+1})^{1/2}} \qquad (2\text{-}4)$$

where

Cov = covariance

Var = variance

k = lag

X_i = variable of data set

which is equivalent to

$$r_k = \frac{\frac{1}{N-k}\sum_{i=1}^{N-k} X_i \cdot X_{i+k} - \frac{1}{(N-k)^2}\left(\sum_{i=1}^{N-k} X_i\right)\left(\sum_{i=1}^{N-k} X_{i+k}\right)}{\left[\frac{1}{N-k}\sum_{i=1}^{N-k} X_i^2 - \frac{1}{(N-k)^2}\left(\sum_{i=1}^{N-k} X_i\right)^2\right]^{1/2}\left[\frac{1}{N-k}\sum_{i=1}^{N-k} X_{i+k}^2 - \frac{1}{(N-k)^2}\left(\sum_{i=1}^{N-k} X_{i+k}\right)^2\right]^{1/2}} \qquad (2\text{-}5)$$

where

N = number of observations in the series

The following confidence intervals are suggested by Chatfield (1975). Upper and lower confidence intervals at 90 percent significance level are defined by:

$$C_{k,u} = \frac{-1 + 1.645\sqrt{N-k}}{N-k}$$
(2-6)
$$C_{k,1} = \frac{-1 + 1.645\sqrt{N-k}}{N-k}$$

where

$C_{k,u}$ = upper confidence limit at lag k

$C_{k,1}$ = lower confidence interval at lag k

N = number of observations in series

k = lag

Interpreting the meaning of a set of autocorrelation coefficients is not easy. If a time series is random, 19 out of 20 of the values of r_k can be expected to lie within the confidence interval at the 95 percent significance level. If a time series contains a certain fluctuation, then the correlogram (a plot of correlation coefficients versus lag) will exhibit an oscillation at the same frequency.

The analysis of a time series which exhibit a long-term change in mean depends on whether one wants to (1) measure the trend or (2) remove the trend in order to analyze local fluctuations. To analyze local fluctuations, an approach of this type is sometimes adequate, particularly if the trend is fairly small, but sometimes a more sophisticated approach is desired. The following techniques for removing trend were proposed by Chatfield (1975):

1. Curve-fitting
2. Filtering
3. Differencing

Of these techniques, differencing is particularly useful for removing a trend. It is simple to difference a given time series until it becomes stationary. This method is particularly stressed by Box and Jenkins (1970). According to Chatfield (1975), first-order differencing is usually sufficient to obtain an apparent stationarity, so that the new series $Y_1, \ldots, Y_{N-1}$ is formed from the original series $X_1, \ldots, X_N$ by:

$$Y_t = X_{t+1} - X_t = \nabla X_{t+1} \qquad (2\text{-}7)$$

Lag Cross Correlation

Assuming that two series X_t and Y_t are correlated means individual observations in the two series are correlated in the same time period. This is known as simple correlation or as lag zero cross correlation. The latter term is used since consideration can also be given to lag k cross correlation. Lag k cross correlation is the correlation between one random variable at one time point and a second random variable k time point later (Yevjevich, 1972).

The cross correlation coefficient can be calculated by substituting Y_{i+k} for X_{i+k} in the autocorrelation equation (2-5):

$$r_k = \frac{\frac{1}{N-k}\sum_{i=1}^{N-k} X_i \cdot Y_{i+k} - \frac{1}{(N-k)^2}\left(\sum_{i=1}^{N-k} X_i\right)\left(\sum_{i=1}^{N-k} Y_{i+k}\right)}{\left[\frac{1}{N-k}\sum_{i=1}^{N-k} X_i^2 - \frac{1}{(N-k)^2}\left(\sum_{i=1}^{N-k} X_i\right)^2\right]^{1/2}\left[\frac{1}{N-k}\sum_{i=1}^{N-k} Y_{i+k}^2 - \frac{1}{(N-k)^2}\left(\sum_{i=1}^{N-k} Y_{i+k}\right)^2\right]^{1/2}} \quad (2\text{-}8)$$

where

r_k = lag k cross correlation coefficient

N = number of observations in the series

k = lag time

X_i, Y_i = series of data

The confidence interval for cross correlation is computed by Equation (2-6).

CHAPTER 3

DESCRIPTION OF THE STUDY AREA

General Description

The study was conducted in two irrigation projects, the Idaho Irrigation District and the Snake River Valley Irrigation District. These are located in Bingham and Bonneville counties in southeastern Idaho (Fig. 3-1). Crops presently grown in the study area are potatoes, grain, and alfalfa for both hay and pasture. Border, furrow, and sprinkler irrigation systems are used to apply water to these crops (Tables 3-1 and 3-2).

The topography of the study area is uniform, with an average slope of 0.002 m/m at an elevation of 1370 to 1460 m. Major soil types of the study area are silt loam, loam, and sandy loam textures. The soils are excessively well drained and have high porosity and permeability. Soil series patterns and locations in the study area are given by Yoo and Busch (1981). They obtained soil survey maps from Soil Conservation Service offices to define the soil patterns of the study area, then digitized and composited boundaries of each soil series with area maps generated from low level infrared aerial photographs (Yoo and Busch, 1980).

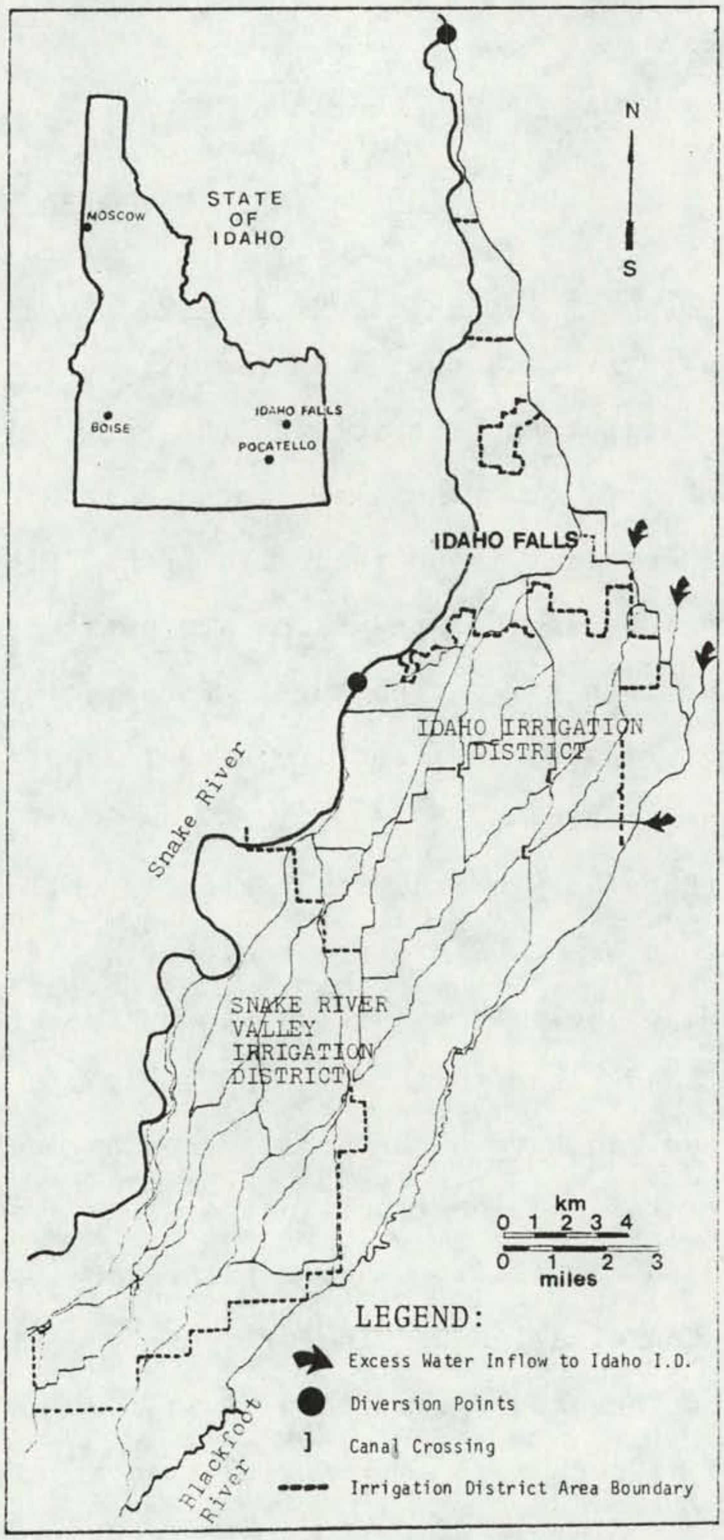

Fig. 3-1.--Map of the Idaho Irrigation District and the Snake River Valley Irrigation District

Table 3-1.--Crop distribution in the Idaho Irrigation District and the Snake River Valley Irrigation District

District	Total area (ha)	Irrigated area (ha)	Crop distribution (%)			
			Potatoes	Grain	Alfalfa	Pasture
Idaho Irrigation District	14,051	11,565	27.2	40.0	19.0	13.8
Snake River Valley Irrigation District	8,892	6,951	26.4	39.9	23.2	10.5
Total	22,943	18,516	26.9	39.9	20.6	12.5

Table 3-2.--On-farm application system distribution in the Idaho Irrigation District and the Snake River Valley Irrigation District

District	Application system (%)				
	Border	Furrow	Hand-move sprinkler	Side-roll sprinkler	Center-pivot sprinkler
Idaho Irrigation District	52.7	10.5	26.2	9.0	1.6
Snake River Valley Irrigation District	49.5	5.8	31.0	12.0	1.7
Total	51.5	8.8	27.9	10.2	1.6

The climate of the area is considered to be semi-arid, with very low rainfall and high temperatures in the summer and low temperatures in the winter. Average annual rainfall for the past 25 years is 242 mm. The maximum average monthly rainfall of 34 mm occurs in June, and the minimum monthly average of 12 mm occurs in July. Mean annual maximum and minimum temperatures are 14°C and -0.5°C, respectively. Mean maximum and minimum temperatures, during the past 25 years, occur in July and January, respectively, and are 30°C and -12°C. The length of growing season in the Idaho Falls area is 120 days, and the average frost-free season is May 15 to September 19 (Khanjani, 1980).

Irrigation water is supplied from the Snake River and delivered through a canal network. According to Netz (1980), the farmers almost always operate canal headgates at the farm delivery site when they feel water is needed. Diversion dams on the river raise the water level enough so that pumping is not necessary to supply the canals.

Idaho Irrigation District

In 1899, Charles Tantphus requested and was appropriated 100,000 miner's inches[1/] of water, to be diverted from the Snake River for the Idaho Canal Company. In 1905, the Idaho Irrigation District was formed, and in 1930 the Idaho Canal was enlarged to convey an additional 8,500 1/s

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[1/] In Idaho, 1 miner's inch is 1/50 cfs (= 0.566 1/s).

to carry the Boomer decree and several laterals were added around that time (Carter, 1955).

Presently the Idaho Irrigation District operates and maintains over 160 km of major canals and over 24 km of the Sand Creek, which supplies water to 11,500 ha of land in the area.

The Idaho Main Canal provides the major source of water to the entire system of canals in the Idaho Irrigation District. Water is diverted out of the Snake River about 13 km north of Idaho Falls near Bear Island. It is transported by means of the Idaho Main Canal to Idaho Falls where its waters are dispersed into several smaller canals for distribution throughout the district. The Main Idaho Canal discharges waste water into the Blackfoot River 60 km of its origin at the Snake River. The present capacity of the Idaho Canal is 45,000 l/s (Netz, 1978).

Snake River Valley Irrigation District

In 1885, William Dye and Lorenzo Firth in concert with George King and Henry R. Whitmall obtained water for their land. They started at a point on the east side of the Snake River about 8 km downstream from Idaho Falls in Bonneville County. In 1889, the capacity of this canal, the Cedar Point Canal, was tripled and the water rights decreed. From that time on, the canal was called the Snake River Valley Canal (Carter, 1955).

Presently the Snake River Valley Irrigation District operates and maintains over 80 km of major canals that supply water to over 6,900 ha of land.

The main Snake River Valley Canal provides the major source of water for the entire Snake River Valley Irrigation District. It parallels the Snake River for about 5 km to attain an elevation high enough for deliveries in the district. It is nearly 32 km from the point that the Snake River Valley Main Canal diverts water from the Snake River to the point where the water distribution ends (Netz, 1980).

CHAPTER 4

DATA ANALYSIS

A major objective of this study was to determine the factors which influence the diversion inflow and the outflow from an irrigation district. To determine the influences of various factors, water flow data, crop water requirements, and precipitation data were analyzed statistically and graphically.

Data for the 1978 and 1979 crop years were analyzed to develop the data analysis procedures used in this study. Data for the 1980 crop year were used to test these procedures.

Consumptive Irrigation Requirements

Estimating Equations and Input Data Requirements

Many methods of determining evapotranspiration (ET) have been proposed. The methods may be broadly classified as those based on combination theory, humidity data, radiation data, and miscellaneous methods which usually involve multiple correlations of ET and various climate data (Burman et al., 1980).

In this study, a computer program written by Allen and Erpenbeck (1979) based on a modified Penman combination method was used. Jensen (1974) stated that combination methods are the most accurate methods for a wide range of climatic conditions. Estimates obtained with a combination equation are reliable for periods from one day to one month.

The modified Penman equation used for estimating an alfalfa based reference ET can be written as:

$$E_{tr} = \frac{\Delta}{\Delta + r} (R_n + G) + \frac{r}{\Delta + r} 15.36\ W_f \cdot (e_a - e_d) \qquad (4\text{-}1)$$

where

E_{tr} = the reference crop ET in cal/cm^2

Δ = the slope of the vapor pressure-temperature curve

r = the phychrometric constant in mb/C

R_n = the net radiation in cal/cm^2

G = the soil heat flux to the surface in cal/cm^2 · d

W_f = the wind function (dimensionless)

$(e_a - e_d)$ = the mean daily vapor pressure deficit in mb

15.36 = a constant of proportionality in cal/cm^2 · d

Further details of calculations can be found in articles by Burman et al. (1980), Jensen (1974), and Wright (1978).

Input data used for estimating ET are described below:

1. Climatological data: Maximum temperature, minimum temperature, dry-bulb temperature, wet-bulb temperature, solar radiation, and wind velocity data were used as input data. These data were measured at Ricks College Weather Station located at Rexburg, Idaho, about 42 km north of Idaho Falls.

2. Crop coefficients: Crop coefficients for Kimberly in southern Idaho were used. These were recently developed by Wright (1979).

3. Other data: Beginning of growing season or planting date, effective cover date, and end of growing season or harvest date, and total area for crops were used as input data. These data are listed in Table 4-1.

Results

Monthly average ET values and accumulated ET values are listed in Table 4-2. Though large fluctuations are apparent in the 1979 data compared with the 1978 data, there is approximately a 4 percent difference in the total accumulated values. The accumulated ET values for 1980 were much higher than the values for 1978 and 1979 (Table 4-2).

Average daily ET estimates from May through October in 1978, 1979, and 1980 in the study area are shown in Fig. 4-1. Due to large day-to-day variations in ET, the ET data were graphed after smoothing. The procedures and computer program for smoothing data are listed in Appendix B. In 1978, 1979, and 1980, the peak ET occurred in July, and decreases occurred in the first part of August due to wheat harvest. In 1979, decreases in ET existed at the end of June and in the first part of August. These decreases appear to be associated with precipitation which occurred with 3 or 4 days duration.

Daily ET values for the different crops and the reference crop in 1979 are shown in Fig. 4-2. For winter wheat, spring wheat, and alfalfa, the peak ET occurred at the same time with approximately the same value. Harvest times are shown as rapid drops in the curves.

Table 4-1.--Beginning of growing season or planting date, effective cover date, end of growing season or harvest date, and total area for crops in the study area

Crop	Total area (ha)	Date (month, day)		
		Beginning of growing season or planting	Effective cover	End of growing season or harvest
Winter wheat	3700	Apr 16	Jul 09	Aug 05
Spring wheat	3700	Apr 20	Jul 19	Aug 25
Alfalfa	3800	Apr 10	May 15	Sep 10
Potatoes	5010	May 10	Jun 29	Sep 10
Pasture	2310	Apr 21	Jun 05	Oct 05

Table 4-2.--Average monthly evapotranspiration in the study area during the 1978, 1979, and 1980 growing seasons

Year	ET (mm/day)						Total (mm)
	May	Jun	Jul	Aug	Sep	Oct	
1978	2.3	5.1	6.1	4.1	1.4	0.7[1/]	565.9
1979	2.4	3.7	6.1	3.9	2.0	0.4	587.2
1980	2.3	5.4	7.0	4.6	1.8	0.5	667.3

[1/] Average ET was calculated by daily ET data measured from October 1 through October 11.

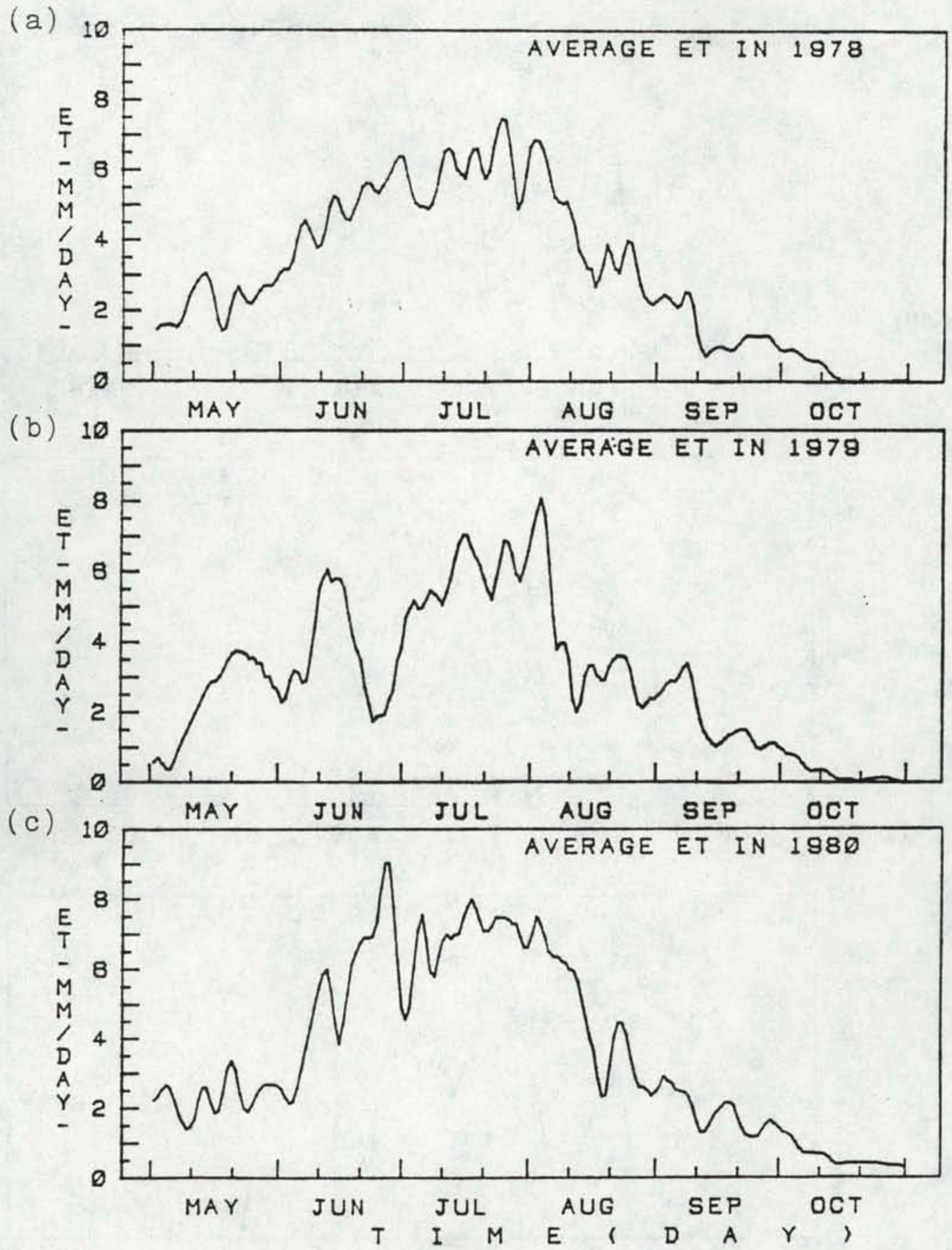


Fig. 4-1.--Average daily evapotranspiration in the study area during 1978, 1979, and 1980 crop years. (a) 1978, (b) 1979, (c) 1980.

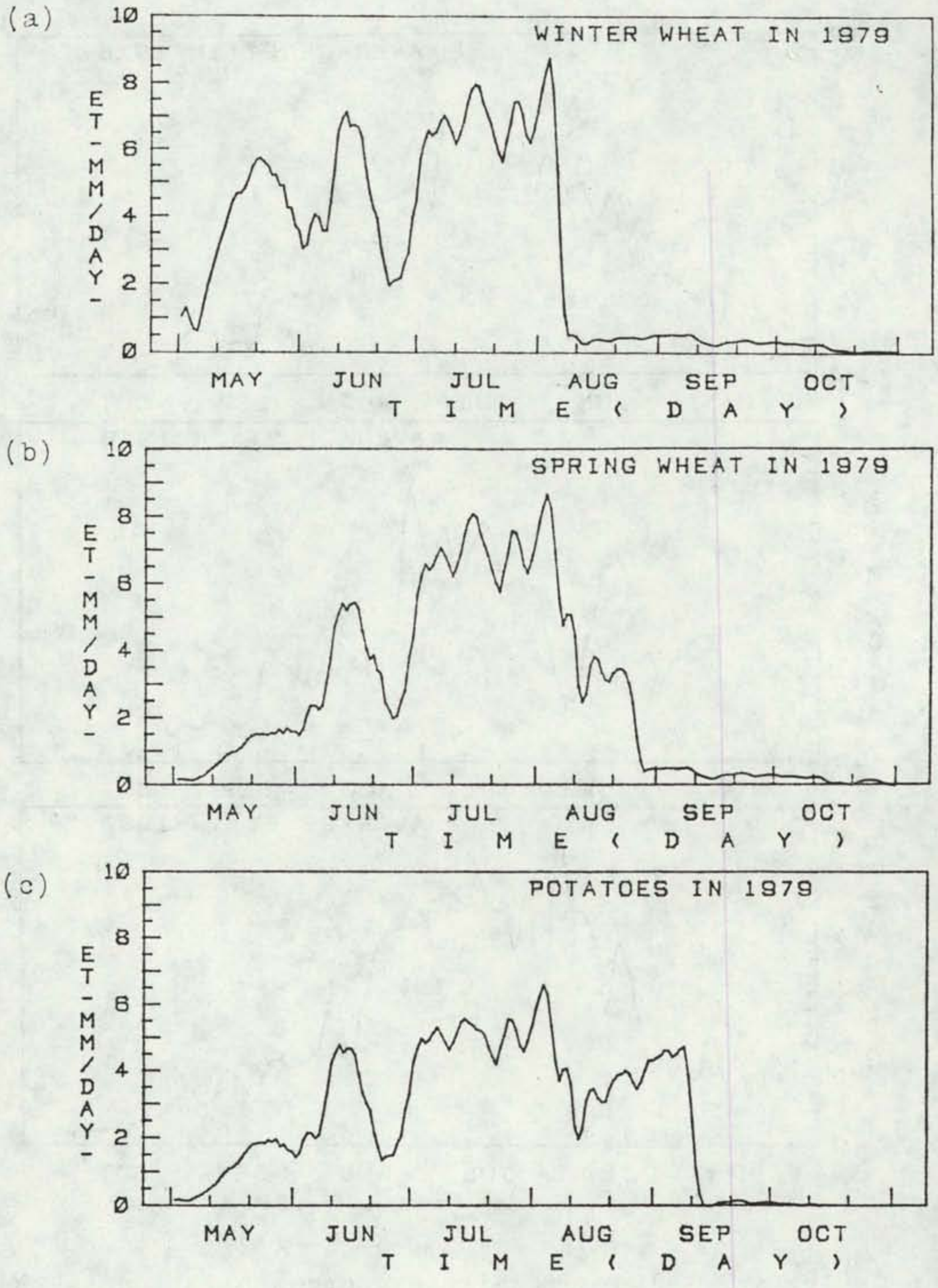


Fig. 4-2.--Daily evapotranspiration of the crops in the study area during the 1979 crop year. (a) winter wheat, (b) spring wheat, (c) potatoes.

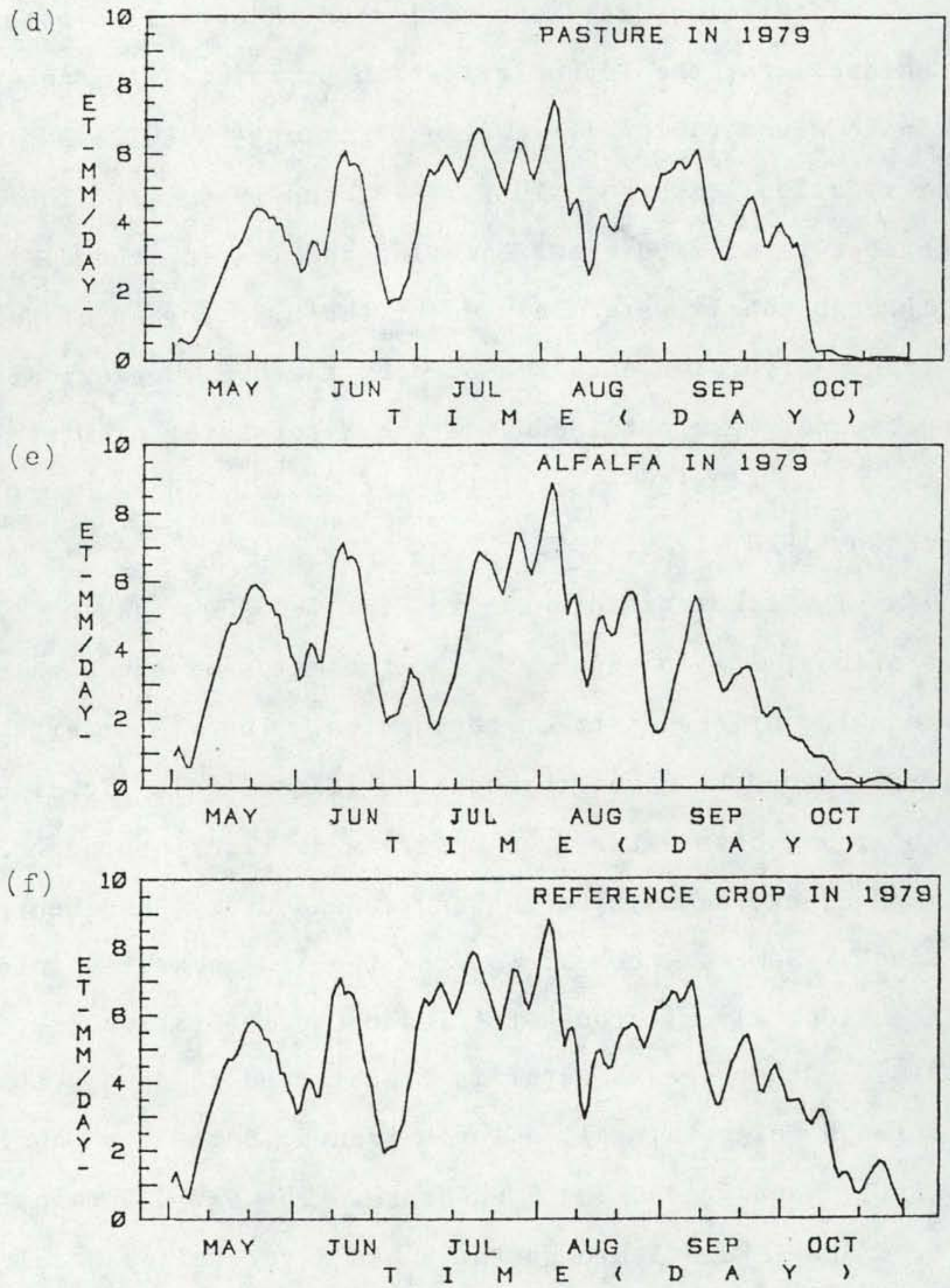


Fig. 4-2.--Continued. (d) pasture, (e) alfalfa, (f) reference crop.

Description of Flow Data

Data Collection

Water flow data were collected to establish water balances for the Idaho Irrigation District (IID) and the Snake River Valley Irrigation District (SRVID). During the irrigation seasons in 1978, 1979, and 1980, all flows except river diversions entering and leaving the districts through canals were measured by the U.S. Bureau of Reclamation. Diversion data measured by the U.S. Geological Survey personnel were obtained from the Watermaster of District No. 01 on a daily basis (District No. 01, Snake River, Idaho, 1978, 1979, 1980).

The schematic diagram in Fig. 4-3 shows gaging stations, station numbers, and the names of the canals measured at the district boundaries. The IID diverts water from the Snake River through the Idaho Canal. It also obtains excess water from upstream districts through Little Sand Creek, Ammon-Lincoln Canal, Sand Creek, and Henry's Creek. Some of the excess from the IID is wasted into the Blackfoot River through the Idaho Canal (Station #20, Fig. 4-3). Other excess water is transferred to the SRVID through Quigg Lateral, Allen's Branch, Butte Arm Canal, Little Sand Creek, and Sand Creek. The SRVID obtains water from Snake River through the Snake River Valley Canal and also receives excess water from the IID. Excess water from

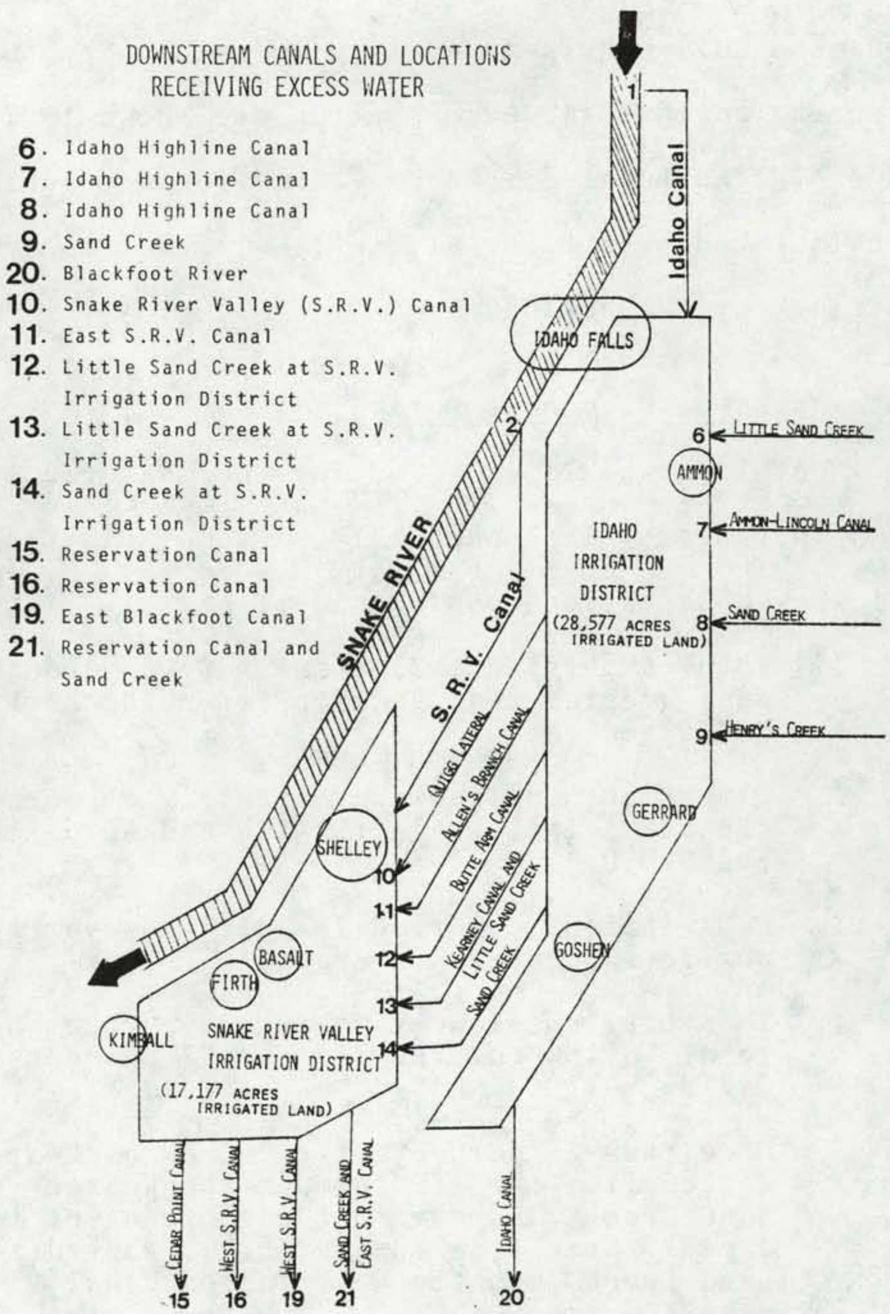


Fig. 4-3.--Schematic diagram of canal network in the study area

the SRVID flows into the Reservation Canal, East Blackfoot Canal, and Sand Creek.

In this study, total inflows and total outflows were used on a daily basis to analyze relationships between them. Measuring periods for each station are shown in Tables 4-3 and 4-4. The total discharge volume for any period of time is calculated by summing all inflows or outflows of a district for the period.

Description of Discharge Data

Monthly accumulated flows for the measured canals are shown in Tables 4-5 through 4-10. From these tables, the following observations can be made:

1. Total diversion inflow in 1979 was about 10 percent greater than in 1978 for both the IID and SRVID.

2. Diversion supplied approximately 90 percent of the total inflows in the IID and 80 percent in the SRVID.

3. Peak inflows occurred in July; however, peak outflows occurred in August.

4. The total outflow was about 20 percent of the total inflow for the IID and 27 percent for the SRVID.

5. More than 65 percent of total excess water was wasted from the IID through the Kearney Waste and Sand Creek, and more than 84 percent of total excess water from the SRVID was wasted through Sand Creek into the Reservation Canal.

Hydrographs of total inflow, total outflow, moving average ET (MAET), and rainfall for the IDD and SRVID in 1978, 1979, and 1980 are shown in Figs. 4-4 through 4-9.

Table 4-3.--Measuring stations, station numbers, and measuring periods of inflow and outflow in the Idaho Irrigation District

Inflow				Outflow			
Station		Measuring period		Station		Measuring period	
No.	Name	Starting	Ending	No.	Name	Starting	Ending
1	Idaho Canal	780505[1/] 790503 800501	781105 791031 801031	10	Quigg Lateral	780627 * *	781009 * *
6	First Sand Creek	780624 790501 800424	781106 791028 801028	11	Allen's Branch	780713 790510 800503	781106 791028 801105
7	Ammon-Lincoln Waste	780627 * *[2/]	781104 * *	12	Butte Arm Waste at Anderson	780627 790509 800510	781028 791030 801105
8	Little Sand at Green	780624 790510 800509	781030 791028 801103	13	Kearney Waste	780802 790509 800502	781107 791030 801104
9	Henry's Creek	780803 790426 800501	781106 791030 801104	14	Sand Creek nr Fieldings	780628 790509 800424	781106 791030 801104
				15	Idaho Waste into Blackfoot River	780706 790601 800502	781028 791029 801105

[1/]Year, month, day.

[2/]Measuring station was withdrawn in 1979 and 1980 due to slight inflow.

Table 4-4.--Measuring stations, station numbers, and measuring periods of inflow and outflow in the Snake River Valley Irrigation District

Inflow				Outflow			
Station		Measuring period		Station		Measuring period	
No.	Name	Starting	Ending	No.	Name	Starting	Ending
2	Snake River Valley Canal	780514[1/] 790504 800501	781110 791031 801031	15	Cedar Point into Blackfoot Canal	780701 790510 800503	781105 791029 801103
10	Quigg Lateral	780627 * *[2/]	781009 * *	16	Cedar Point into Reservation	780621 790601 800523	781105 791022 801105
11	Allen's Branch	780713 790510 800502	781106 791028 801105	19	Sand Creek into Reservation	780615 790501 800514	781101 791029 801120
12	Butte Arm Waste at Anderson	780627 790509 800510	781028 791030 801105	21	Odd Ball	780621 790509 800430	781105 791031 801105
13	Kearney Waste	780802 790509 800502	781107 791030 801104				
14	Sand Creek near Fielding	780628 790509 800424	781106 791030 801104				

[1/]Year, month, day.

[2/]Measuring station was withdrawn in 1979 and 1980 due to slight inflow.

Table 4-5.--Monthly accumulated flows in the Idaho Irrigation District during the 1978 crop year

Station		Monthly accumulated flow (1000 m^3)								Total	
		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	(1000 m^3)	(%)
Inflow	1	*[1/]	36,277	83,414	100,063	72,356	44,559	29,305	*	365,975	(89.3)
	6	*	*	1,837	2,749	3,369	5,113	6,904	2,130	22,101	(5.4)
	7	*	*	203	1,235	1,261	384	1,105	128	4,316	(1.1)
	8	*	*	543	2,035	2,546	2,688	1,299	*	9,110	(2.2)
	9	*	*	*	*	2,723	2,801	2,478	241	8,243	(2.0)
Total		*	36,277	85,997	106,083	82,544	55,544	41,090	2,499	409,746	(100.0)
(Percent)			(8.9)	(21.0)	(25.9)	(20.0)	(13.6)	(10.0)	(0.6)	(100.0)	
Outflow	10	*	*	223	798	768	602	58	*	2,450	(4.0)
	11	*	*	*	930	1,264	1,182	1,094	158	4,628	(7.6)
	12	*	*	80	838	919	534	514	*	2,885	(4.7)
	13	*	*	*	*	5,985	3,660	3,320	381	13,346	(21.8)
	14	*	*	232	3,683	6,478	7,481	7,671	1,100	26,645	(43.5)
	20	*	*	*	2,698	3,370	2,616	2,638	*	11,322	(18.5)
Total		*	*	535	8,946	18,784	16,075	15,294	1,639	61,276	(100.0)
(Percent)				(0.9)	(14.6)	(30.7)	(26.2)	(25.0)	(2.7)	(100.0)	
Inflow - outflow		*	36,277	85,462	91,137	63,470	39,470	25,794	860	348,470	
(Percent)			(10.4)	(24.5)	(27.9)	(18.2)	(11.3)	(7.4)	(0.2)	(100.0)	

[1/] No measurement during the month.

Table 4-6.--Monthly accumulated flows in the Idaho Irrigation District during the 1979 crop year

Station		Monthly accumulated flow (1000 m^3)								Total	
		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	(1000 m^3)	(%)
Inflow	1	* 1/	51,940	80,731	101,539	71,573	70,115	35,424	*	411,322	(91.0)
	6	112	3,160	2,572	1,776	3,124	1,267	858	*	12,870	(2.8)
	7	*	*	*	*	*	*	*	*		
	8	*	1,743	2,344	2,443	3,196	1,669	1,262	*	12,657	(2.8)
	9	150	2,347	2,251	2,059	3,528	3,059	1,837	*	15,231	(3.4)
Total		262	59,190	87,898	107,817	81,421	76,110	39,381	*	452,080	(100.0)
(Percent)		(0.1)	(13.1)	(19.4)	(23.8)	(18.0)	(16.8)	(8.7)		(100.0)	
Outflow	10	*	*	*	*	*	*	*	*		
	11	*	340	200	180	57	48	9	*	834	(0.8)
	12	*	501	838	836	957	928	756	*	4,815	(4.9)
	13	*	3,866	6,678	6,569	8,579	6,700	7,381	*	39,773	(40.1)
	14	*	4,051	6,285	5,651	7,976	4,143	8,675	*	36,799	(37.1)
	20	*	1,412	3,355	1,793	4,769	2,128	3,433	*	16,890	(17.0)
Total		*	10,170	17,355	15,030	22,337	13,947	20,273	*	99,111	(100.0)
(Percent)			(10.3)	(17.5)	(15.2)	(22.5)	(14.1)	(20.5)		(100.0)	
Inflow - outflow		262	49,020	70,543	92,787	59,084	62,163	19,108	*	352,968	
(Percent)		(0.1)	(13.9)	(20.0)	(26.3)	(16.7)	(17.6)	(5.4)		(100.0)	

1/ No measurement during the month.

Table 4-7.--Monthly accumulated flows in the Idaho Irrigation District during the 1980 crop year

Station		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Total (1000 m^3)	(%)
		Monthly accumulated flow (1000 m^3)									
Inflow	1	*[1/]	34,839	69,372	101,610	69,988	45,063	27,528	*	348,400	(90.9)
	6	575	1,871	1,620	1,138	1,147	1,317	645	*	8,313	(2.2)
	7	*	*	*	*	*	*	*	*		
	8	*	2,990	2,754	1,560	1,684	2,659	1,348	42	13,037	(3.4)
	9	*	3,237	2,578	1,784	2,759	2,162	1,051	130	13,701	(3.6)
	Total	575	42,937	76,324	106,092	75,578	51,201	30,572	172	383,451	(100.0)
	(%)	(0.1)	(11.2)	(19.9)	(27.7)	(19.7)	(13.4)	(8.0)	(0.0)	(100.0)	
Outflow	10	*	*	*	*	*	*	*	*		
	11	*	1,565	1,243	1,890	1,101	607	769	98	7,273	(6.3)
	12	*	293	428	555	623	322	371	19	2,611	(2.3)
	13	*	6,304	6,086	5,212	6,798	5,827	5,601	494	36,322	(31.4)
	14	428	7,694	5,136	2,344	6,343	6,016	2,741	393	31,095	(26.9)
	20	*	7,693	6,565	4,740	8,315	5,014	4,947	870	38,414	(33.2)
	Total	428	23,819	19,458	14,741	23,180	17,786	14,429	1,874	115,715	(100.0)
	(%)	(0.4)	(20.6)	(16.8)	(12.7)	(20.0)	(15.4)	(12.5)	(1.6)	(100.0)	
Inflow - outflow		147	19,118	56,866	91,351	52,398	33,415	16,143	-1,702	267,736	
	(%)	(0.1)	(7.1)	(21.2)	(34.1)	(19.6)	(12.5)	(6.0)	(-0.6)	(100.0)	

[1/] No measurement during the month.

Table 4-8.--Monthly accumulated flows in the Snake River Valley Irrigation District during the 1978 crop year

Station		Monthly accumulated flow (1000 m^3)								Total	
		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	(1000 m^3)	(%)
Inflow	2	*[1]	16,081	54,156	59,233	45,102	30,941	31,260	*	236,773	(82.6)
	10	*	*	223	798	768	602	58	*	2,450	(0.9)
	11	*	*	*	930	1,264	1,182	1,094	158	4,628	(1.6)
	12	*	*	80	838	919	534	514	*	2,885	(1.0)
	13	*	*	*	*	5,984	3,660	3,320	381	13,346	(4.7)
	14	*	*	232	3,683	6,478	7,481	7,671	1,100	26,645	(9.3)
Total		*	16,081	54,692	65,482	60,516	44,400	43,918	1,639	286,727	(100.0)
(%)			(5.6)	(19.1)	(22.8)	(21.1)	(15.5)	(15.3)	(0.6)	(100.0)	
Outflow	15	*	*	*	470	1,027	354	585	194	2,630	(3.4)
	16	*	*	62	294	562	359	878	146	2,300	(3.0)
	19	*	*	5,306	11,421	19,474	14,750	13,482	*	64,432	(84.5)
	21	*	*	387	1,014	1,777	1,511	1,987	223	6,889	(9.0)
Total		*	*	5,744	13,198	22,841	16,974	16,932	562	76,252	(100.0)
(%)				(7.5)	(17.3)	(30.0)	(22.3)	(22.2)	(0.7)	(100.0)	
Inflow - outflow		*	16,081	48,948	52,284	37,675	27,426	26,986	1,077	210,476	
(%)			(7.6)	(23.3)	(24.8)	(17.9)	(13.0)	(12.8)	(0.5)	(100.0)	

[1] No measurement during the month.

Table 4-9.--Monthly accumulated flows in the Snake River Valley Irrigation District during the 1979 crop year

Station		Monthly accumulated flow (1000 m^3)								Total	
		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	(1000 m^3)	(%)
Inflow	2	*[1/]	40,571	52,480	58,886	45,298	37,743	25,966	*	260,943	(76.0)
	10	*	*	*	*	*	*	*	*		
	11	*	340	200	180	57	48	9	*	834	(0.2)
	12	*	501	838	836	957	928	756	*	4,815	(1.4)
	13	*	3,866	6,678	6,569	8,579	6,700	7,381	*	39,773	(11.6)
	14	*	4,051	6,285	5,651	7,976	4,143	8,695	*	36,799	(10.7)
	Total	*	49,329	66,480	72,122	62,866	49,562	42,806	*	343,165	(100.0)
	(%)		(14.4)	(19.4)	(21.0)	(18.3)	(14.4)	(12.5)		(100.0)	
Outflow	15	*	255	696	312	379	661	1,025	*	3,328	(3.6)
	16	*	218	190	174	677	746	667	*	2,673	(2.8)
	19	*	7,604	12,565	13,888	20,986	14,063	12,658	*	81,764	(89.0)
	21	*	417	764	920	1,320	731	1,039	*	5,190	(4.6)
	Total	*	8,495	14,214	15,294	23,362	16,202	15,389	*	92,955	(100.0)
	(%)		(9.1)	(15.3)	(16.5)	(25.1)	(17.4)	(16.6)		(100.0)	
Inflow - outflow		*	40,834	52,266	56,828	39,504	33,360	27,417	*	250,210	
	(%)		(16.3)	(20.9)	(22.7)	(15.8)	(13.3)	(11.0)		(100.0)	

[1/] No measurement during the month.

Table 4-10.--Monthly accumulated flows in the Snake River Valley Irrigation District during the 1980 crop year

Station		Monthly accumulated flow (1000 m^3)								Total	
		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	(1000 m^3)	(%)
Inflow	2	*1/	32,979	41,227	60,782	46,355	35,387	29,667	*	246,397	(26.1)
	10	*	*	*	*	*	*	*	*		
	11	*	1,565	1,243	1,890	1,101	607	769	98	7,273	(2.2)
	12	*	293	428	555	623	322	371	19	2,611	(0.8)
	13	*	6,304	6,086	5,212	6,798	5,827	5,601	494	36,322	(11.2)
	14	428	7,694	5,136	2,344	6,343	6,016	2,741	393	31,095	(9.6)
Total		428	48,835	54,120	70,783	61,220	48,159	39,149	1,004	323,698	(100.0)
(%)		(0.1)	(15.1)	(16.7)	(21.9)	(18.9)	(14.9)	(12.1)	(0.3)	(100.0)	
Outflow	15	*	886	871	378	833	931	1,936	141	5,976	(5.4)
	16	*	275	877	372	574	514	601	78	3,291	(3.0)
	19	*	10,471	14,916	8,156	24,656	17,326	15,542	5,362	96,429	(87.2)
	22	4	623	764	292	482	850	1,575	274	4,864	(4.4)
Total		4	12,255	17,428	9,198	26,545	19,621	19,654	5,855	110,569	(100.0)
(%)		(0.0)	(11.1)	(15.8)	(8.3)	(24.0)	(17.7)	(17.8)	(5.3)	(100.0)	
Inflow - outflow		424	36,580	36,692	61,585	34,675	28,538	19,495	-4,851	213,138	
(%)		(0.2)	(17.2)	(17.2)	(28.9)	(16.3)	(13.4)	(9.1)	(-2.3)	(100.0)	

1/ No measurement during the month.

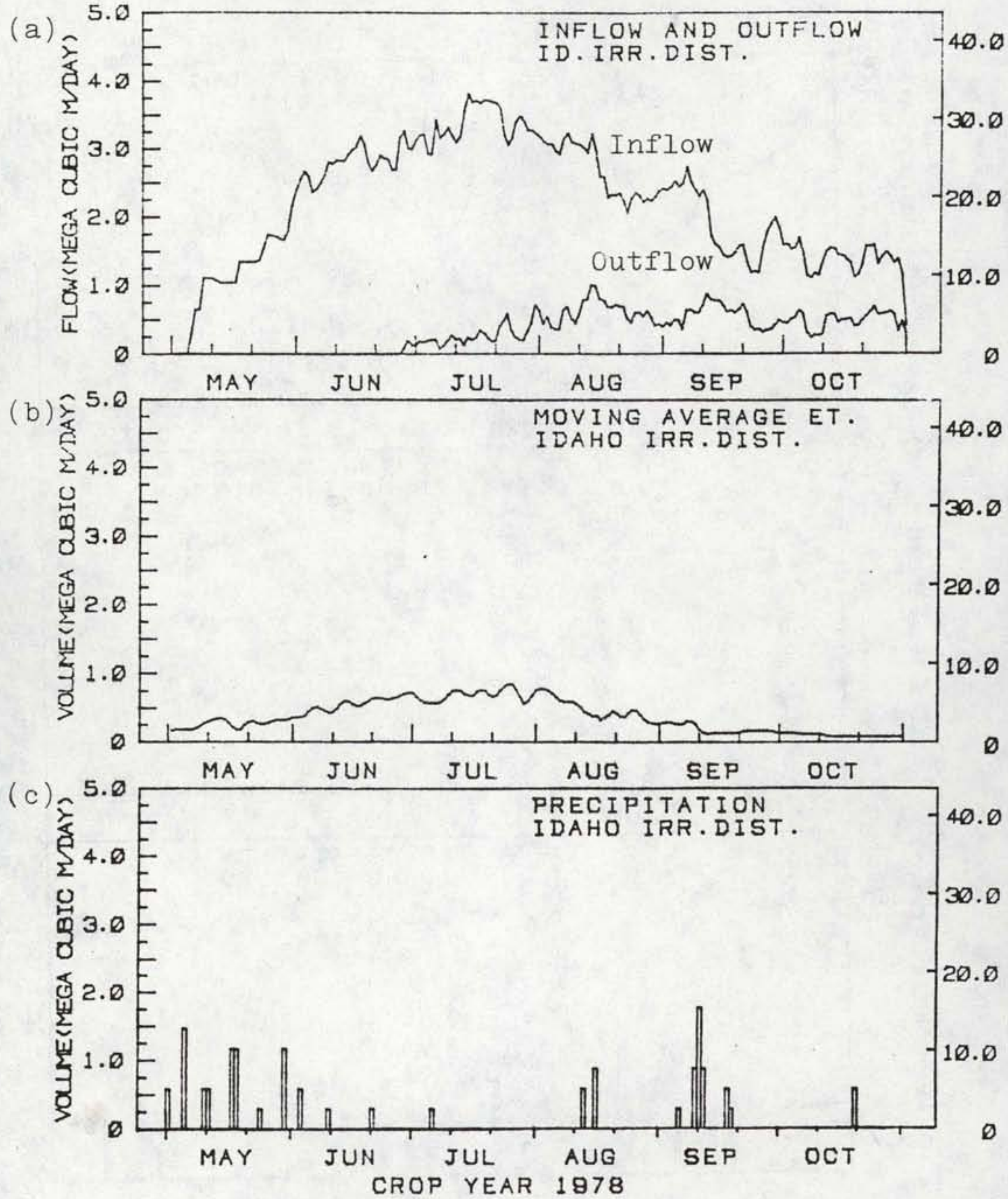


Fig. 4-4.--Daily flow rate, moving average ET, and precipitation in the Idaho Irrigation District during the 1978 crop year. (a) inflow and outflow, (b) moving average, (c) precipitation.

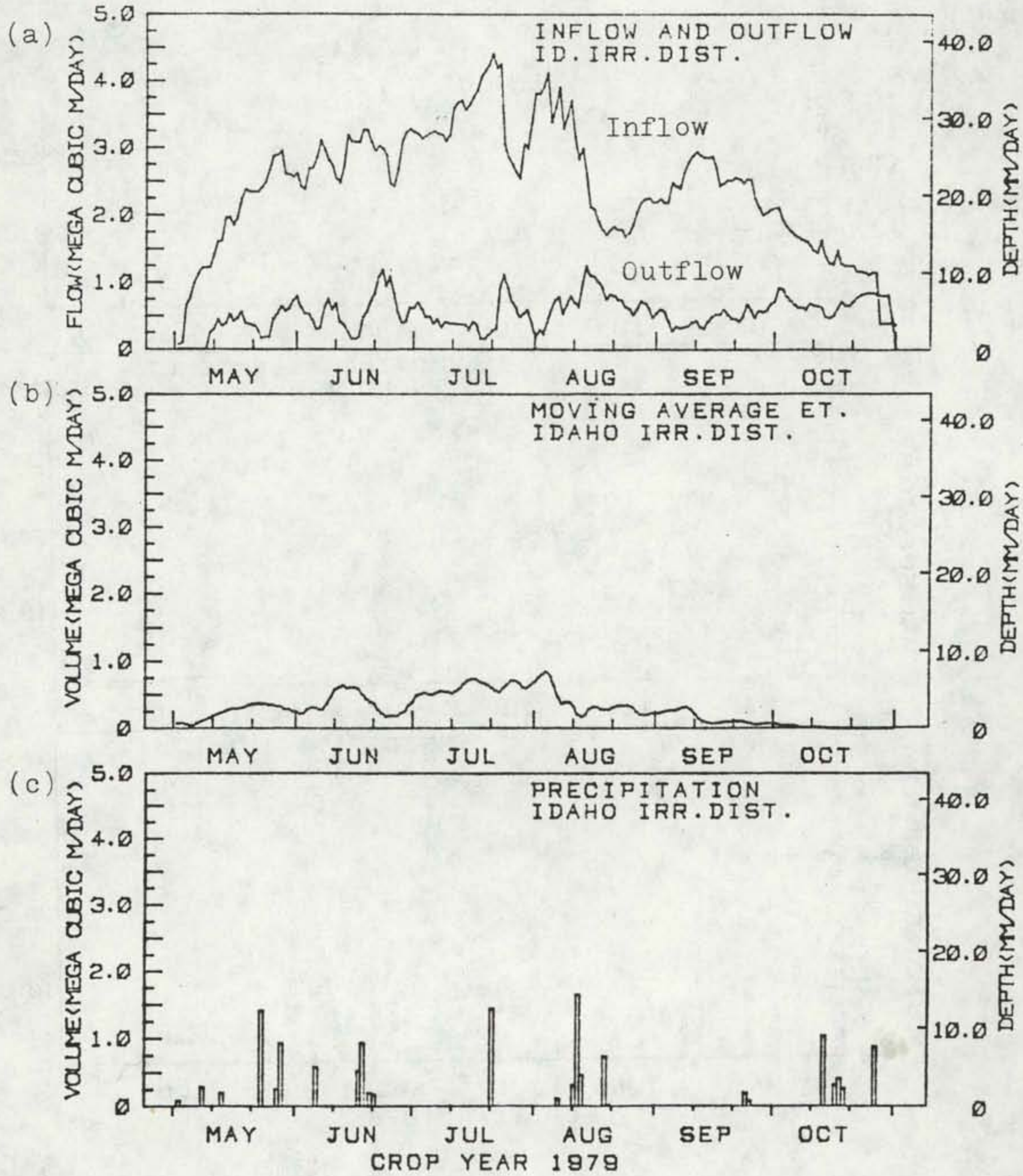


Fig. 4-5.--Daily flow rate, moving average ET, and precipitation in the Idaho Irrigation District during the 1979 crop year. (a) inflow and outflow, (b) moving average ET, (c) precipitation.

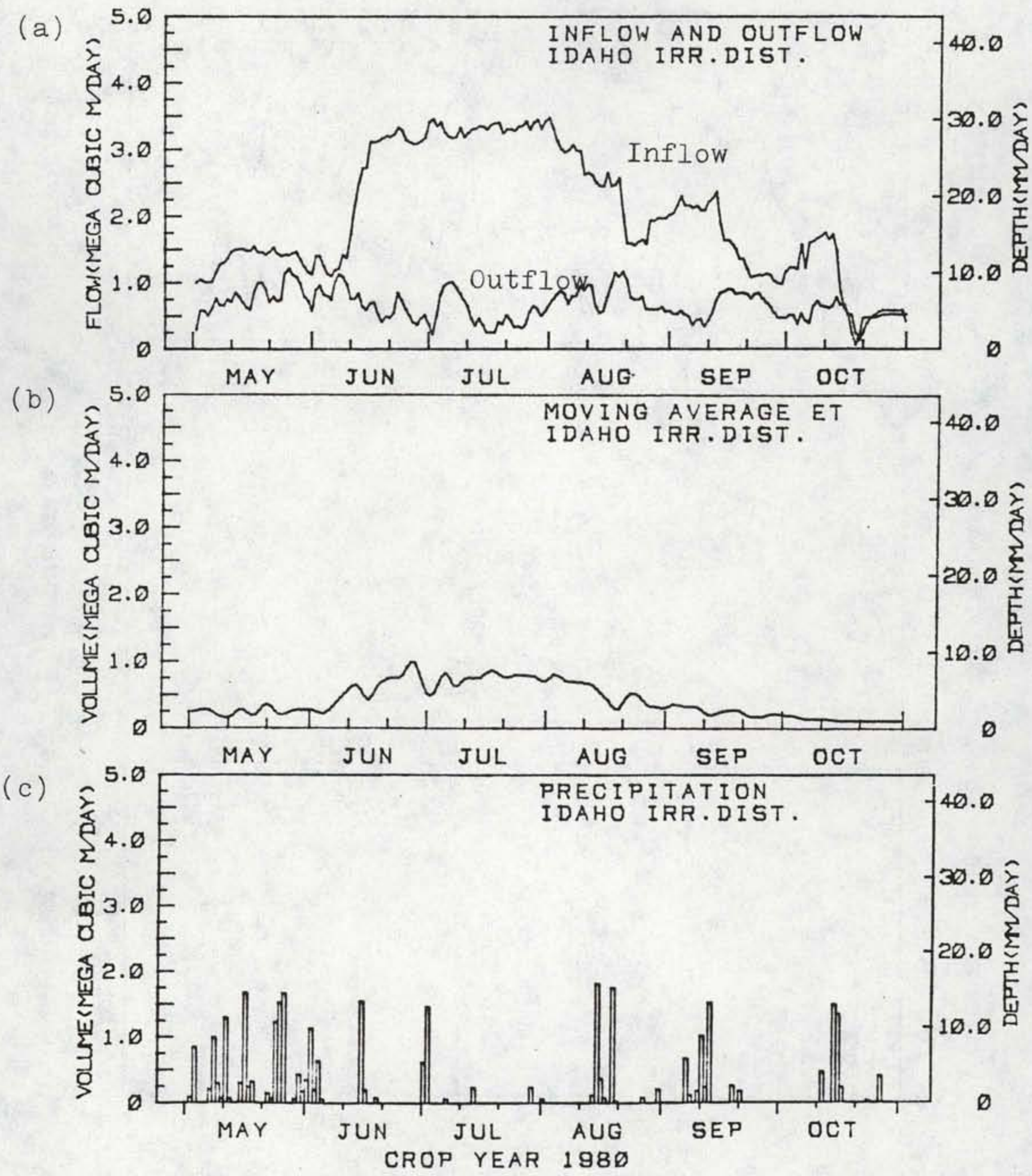


Fig. 4-6.--Daily flow rate, moving average ET, and precipitation in the Idaho Irrigation District during the 1980 crop year. (a) inflow and outflow, (b) moving average ET, (c) precipitation.

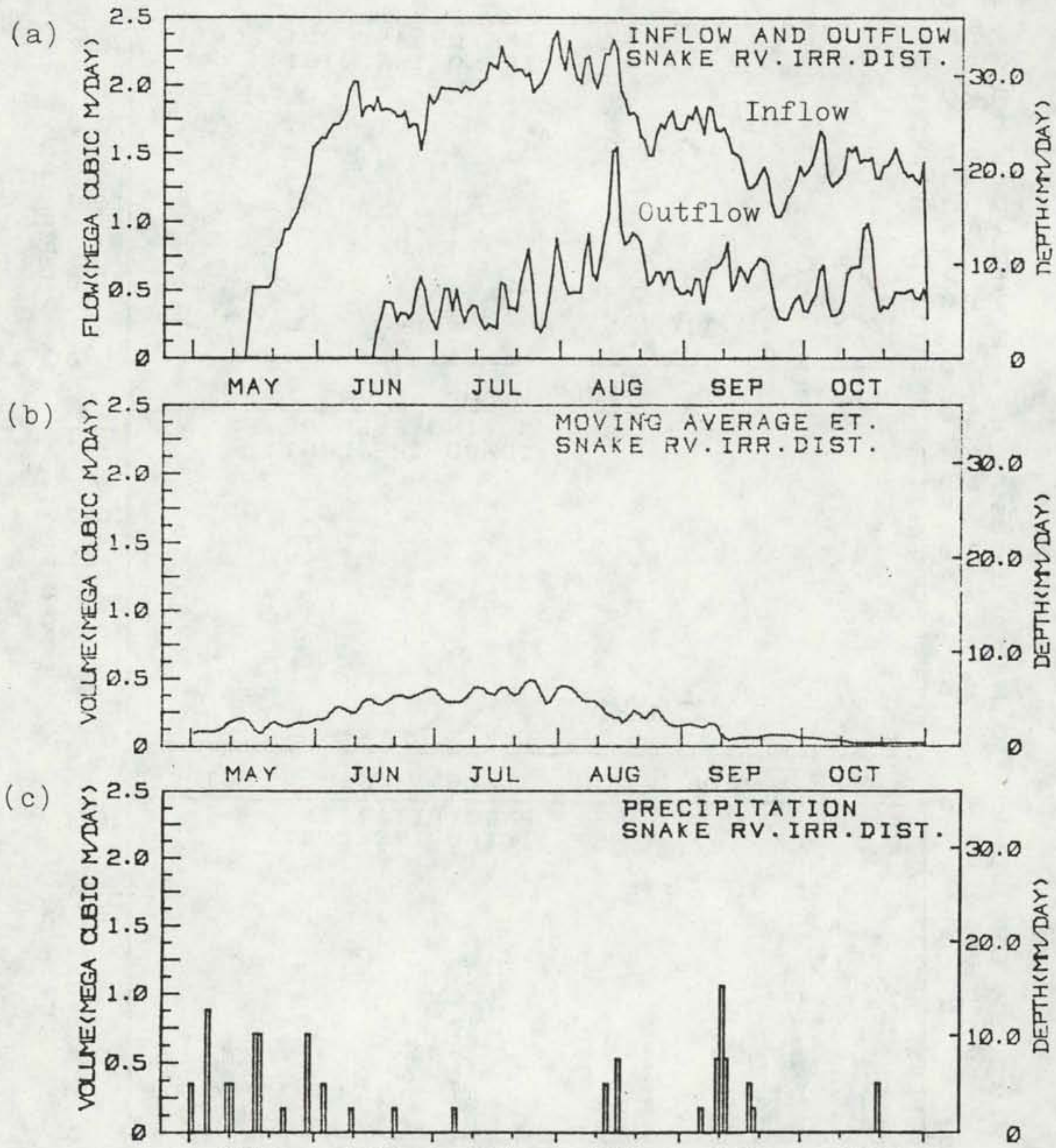


Fig. 4-7.--Daily flow rate, moving average ET, and precipitation in the Snake River Valley Irrigation District during the 1978 crop year. (a) inflow and outflow, (b) moving average ET, (c) precipitation.

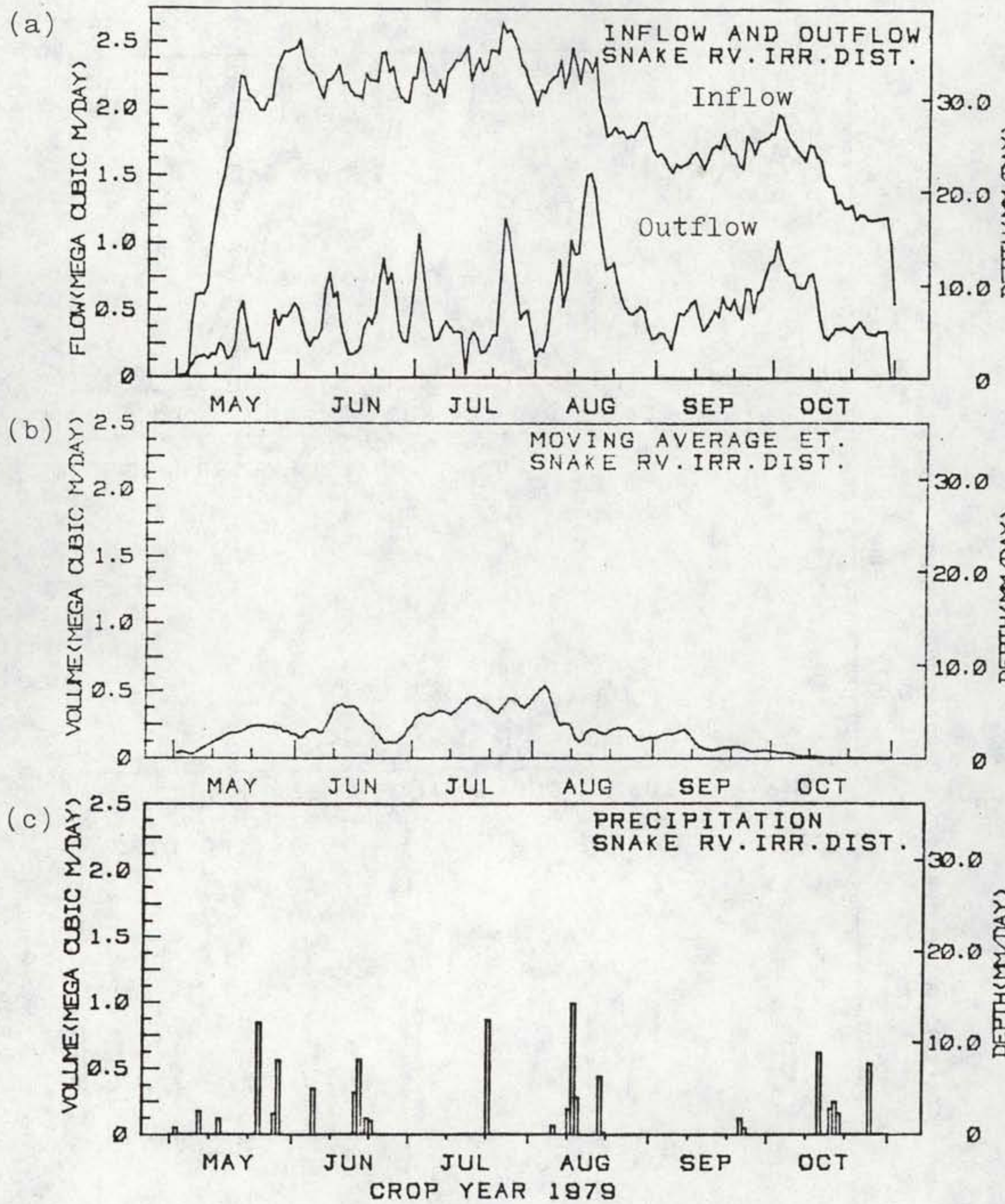


Fig. 4-8.--Daily flow rate, moving average ET, and precipitation in the Snake River Valley Irrigation District during the 1979 crop year. (a) inflow and outflow, (b) moving average ET, (c) precipitation.

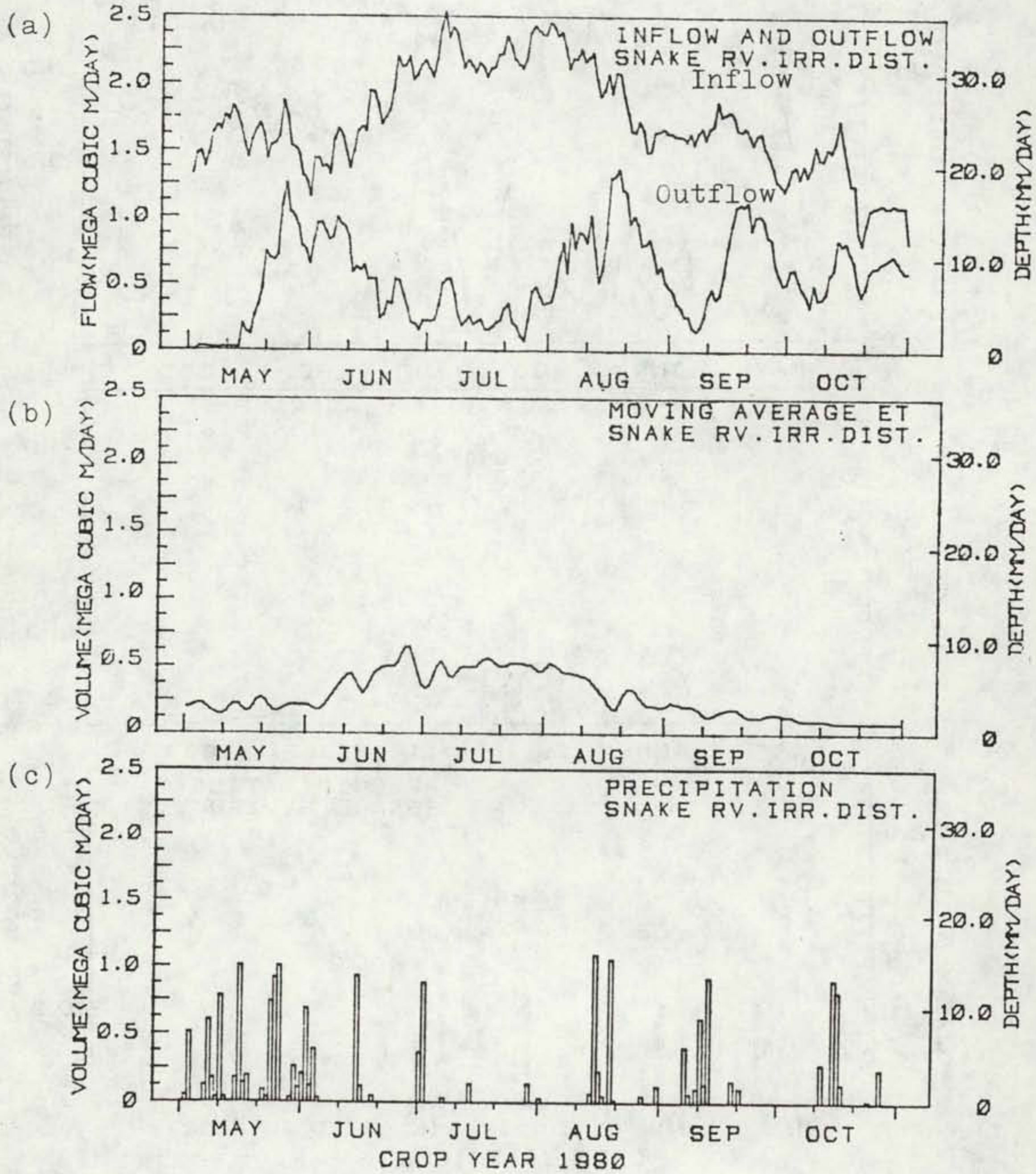


Fig. 4-9.--Daily flow rate, moving average ET, and precipitation in the Snake River Valley Irrigation District during the 1980 crop year. (a) inflow and outflow, (b) moving average ET, (c) precipitation.

Rainfall and ET volumes were calculated by multiplying measured and estimated depths by the appropriate areas. The following things are shown in these graphs:

1. More fluctuations occurred in inflow, outflow, and MAET in 1979 than in 1978 and 1980.

2. During May, more rainfall occurred in 1978 and 1980 than in 1979, and more inflow was supplied in 1979 and 1980 than in 1978.

3. Peak outflow may be related to rainfall.

4. For outflow, a frequency exists.

5. Outflow may be related to inflow with some lag time.

6. Inflows are much greater than MAET with a slight change of MAET resulting in a large change in inflow.

Total inflow, total outflow, evapotranspiration, and precipitation data for the study area are listed in Appendix A.

Statistical Analysis

One method of comparing two sets of paired variables is to determine statistical relationships between the variables. The relationships are characterized in statistical terms by the correlation coefficients, standard deviations, confidence limits, and tests for significance.

Table 4-11 contains the mean, standard deviation, total, minimum, and maximum of the different variables as computed by Statistical Analysis System (SAS, 1979). From these results, the following effects can be noted.

Table 4-11.--Mean, standard deviation, total, minimum, and maximum of inflow, outflow, ET, and precipitation from May 16 through October 31 in 1978 and 1979

Variable	Daily average depth[1] (mm/day)				Total (mm)
	Mean	Standard deviation	Minimum	Maximum	
II8[2]	20.14	7.16	3.19	33.55	3,441
IO8	3.03	2.33	0.00	8.93	516
SI8	24.10	6.08	4.65	35.06	4,097
SO8	6.40	4.25	0.00	22.33	1,089
II9	22.15	7.40	2.79	38.60	3,766
IO9	4.92	2.02	0.00	11.11	836
SI9	28.05	5.81	7.32	38.19	4,772
SO9	7.67	4.01	0.28	22.33	1,304
ET8	3.27	2.41	0.00	8.26	556
ET9	3.22	2.32	0.00	9.88	549
PC8	0.58	2.14	0.00	15.24	99
PC9	0.66	2.25	0.00	14.22	113

[1] Daily average depth = total volume per day/total area.

[2] II8 = Idaho Irrigation District inflow total in 1978.
II9 = Idaho Irrigation District inflow total in 1979.
IO8 = Idaho Irrigation District outflow total in 1978.
IO9 = Idaho Irrigation District outflow total in 1979.
SI8 = Snake River Valley Irrigation District inflow total in 1978.
SI9 = Snake River Valley Irrigation District inflow total in 1979.
SO8 = Snake River Valley Irrigation District outflow total in 1978.
SO9 = Snake River Valley Irrigation District outflow total in 1979.
ET8 = Evapotranspiration of study area in 1978.
ET9 = Evapotranspiration of study area in 1979.
PC8 = Precipitation of study area in 1978.
PC9 = Precipitation of study area in 1979.

1. Inflow has less coefficient of variation (standard deviation/mean) than outflow. In other words, inflow has less fluctuation than outflow.

2. Regardless of the year, standard deviations are nearly the same for ET and precipitation.

Linear Correlation

Linear correlations between the variables as computed by SAS (1979) are shown in Table 4-12. The results show that:

1. Generally, there are negative correlations between inflow and outflow on the same day. However, owing to the lag time from the diversion to the waste, these negative relationships do not necessarily mean that increasing inflow results in decreasing outflow.

2. Significant positive correlation exists between inflow and evapotranspiration. On the other hand, outflow and evapotranspiration are negatively correlated.

3. There are no significant relationships between precipitation and the other variables on the same day. Even though insignificant, precipitation and evapotranspiration are negatively correlated.

4. With the exception of precipitation, significant correlation exists between variables regardless of years and districts.

Autocorrelation

Autocorrelation coefficients were computed to investigate the sequential properties of the inflow and outflow in the study area. A computer program was developed to compute the autocorrelation coefficients and the confidence intervals for a set of data. This program is listed in Appendix C.

Table 4-12.--Correlation coefficient and probabilities among inflow, outflow, evapotranspiration, and precipitation

CORRELATION COEFFICIENTS / PROB > |R| UNDER H0:RHO=0 / N = 170

	II8	IO8	SI8	SO8	II9	IO9	SI9	SO9	ET8	ET9	PC8	PC9
II8	1.00000	-0.17495	0.85181	0.01623	0.77319	-0.04562	0.71119	0.06524	0.85618	0.74338	-0.08048	-0.01242
	0.0000	0.0225	0.0001	0.8336	0.0001	0.5547	0.0001	0.3979	0.0001	0.0001	0.2968	0.8723
IO8	-0.17495	1.00000	0.19998	0.86900	-0.27312	0.27423	-0.46813	0.36451	-0.33523	-0.28544	0.05413	0.06257
	0.0225	0.0000	0.0089	0.0001	0.0003	0.0003	0.0001	0.0001	0.0001	0.0002	0.4832	0.4176
SI8	0.85181	0.19998	1.00000	0.33868	0.56280	0.13400	0.44611	0.21331	0.64920	0.53368	-0.14941	0.01678
	0.0001	0.0089	0.0000	0.0001	0.0001	0.0815	0.0001	0.0052	0.0001	0.0001	0.0518	0.8281
SO8	0.01623	0.86900	0.33868	1.00000	-0.15212	0.33679	-0.30793	0.43728	-0.14399	-0.20446	-0.00915	0.14497
	0.8336	0.0001	0.0001	0.0000	0.0477	0.0001	0.0001	0.0001	0.0610	0.0075	0.9058	0.0593
II9	0.77319	-0.27312	0.56280	-0.15212	1.00000	-0.27123	0.77596	-0.03034	0.75769	0.71449	0.03253	-0.02032
	0.0001	0.0003	0.0001	0.0477	0.0000	0.0003	0.0001	0.6945	0.0001	0.0001	0.6737	0.7926
IO9	-0.04562	0.27423	0.13400	0.33679	-0.27123	1.00000	0.10653	0.77664	-0.06528	-0.25721	-0.02643	0.22311
	0.5547	0.0003	0.0815	0.0001	0.0003	0.0000	0.1668	0.0001	0.3977	0.0007	0.7322	0.0034
SI9	0.71119	-0.46813	0.44611	-0.30793	0.77596	0.10653	1.00000	0.25952	0.75737	0.66430	0.02530	0.07310
	0.0001	0.0001	0.0001	0.0001	0.0001	0.1668	0.0000	0.0006	0.0001	0.0001	0.7433	0.3434
SO9	0.06524	0.36451	0.21331	0.43728	-0.03034	0.77664	0.25952	1.00000	0.02636	-0.08986	0.04975	0.17361
	0.3979	0.0001	0.0052	0.0001	0.6945	0.0001	0.0006	0.0000	0.7330	0.2439	0.5194	0.0236
ET8	0.85618	-0.33523	0.64920	-0.14399	0.75769	-0.06528	0.75737	0.02636	1.00000	0.75792	-0.20392	-0.03196
	0.0001	0.0001	0.0001	0.0610	0.0001	0.3977	0.0001	0.7330	0.0000	0.0001	0.0076	0.6790
ET9	0.74338	-0.28544	0.53368	-0.20446	0.71449	-0.25721	0.66430	-0.08986	0.75792	1.00000	-0.06761	-0.12696
	0.0001	0.0002	0.0001	0.0075	0.0001	0.0007	0.0001	0.2439	0.0001	0.0000	0.3810	0.0990
PC8	-0.08048	0.05413	-0.14941	-0.00915	0.03253	-0.02643	0.02530	0.04975	-0.20392	-0.06761	1.00000	-0.01954
	0.2968	0.4832	0.0518	0.9058	0.6737	0.7322	0.7433	0.5194	0.0076	0.3810	0.0000	0.8003
PC9	-0.01242	0.06257	0.01678	0.14497	-0.02032	0.22311	0.07310	0.17361	-0.03196	-0.12696	-0.01954	1.00000
	0.8723	0.4176	0.8281	0.0593	0.7926	0.0034	0.3434	0.0236	0.6790	0.0990	0.8003	0.0000

Note: The variable names are listed in Table 4-11, p. 54.

For inflow and outflow data, it was simple and effective to use the first-order differencing technique described in Chapter 2 to remove the trend. After removing the trend by differencing using Equation (2-7), autocorrelation coefficients were calculated on a daily basis. Figures 4-10 and 4-11 are the autocorrelograms. From these graphs the following relationships can be found.

1. In the series of inflow data, most correlation coefficients lie between the confidence intervals. It can be interpreted that no particular frequency exists within the series.

2. In the series of outflow data, the correlation coefficients at 7 days and 14 days are significantly higher than zero. Consequently, it can be said that the water use in the study area fluctuates on a weekly cycle.

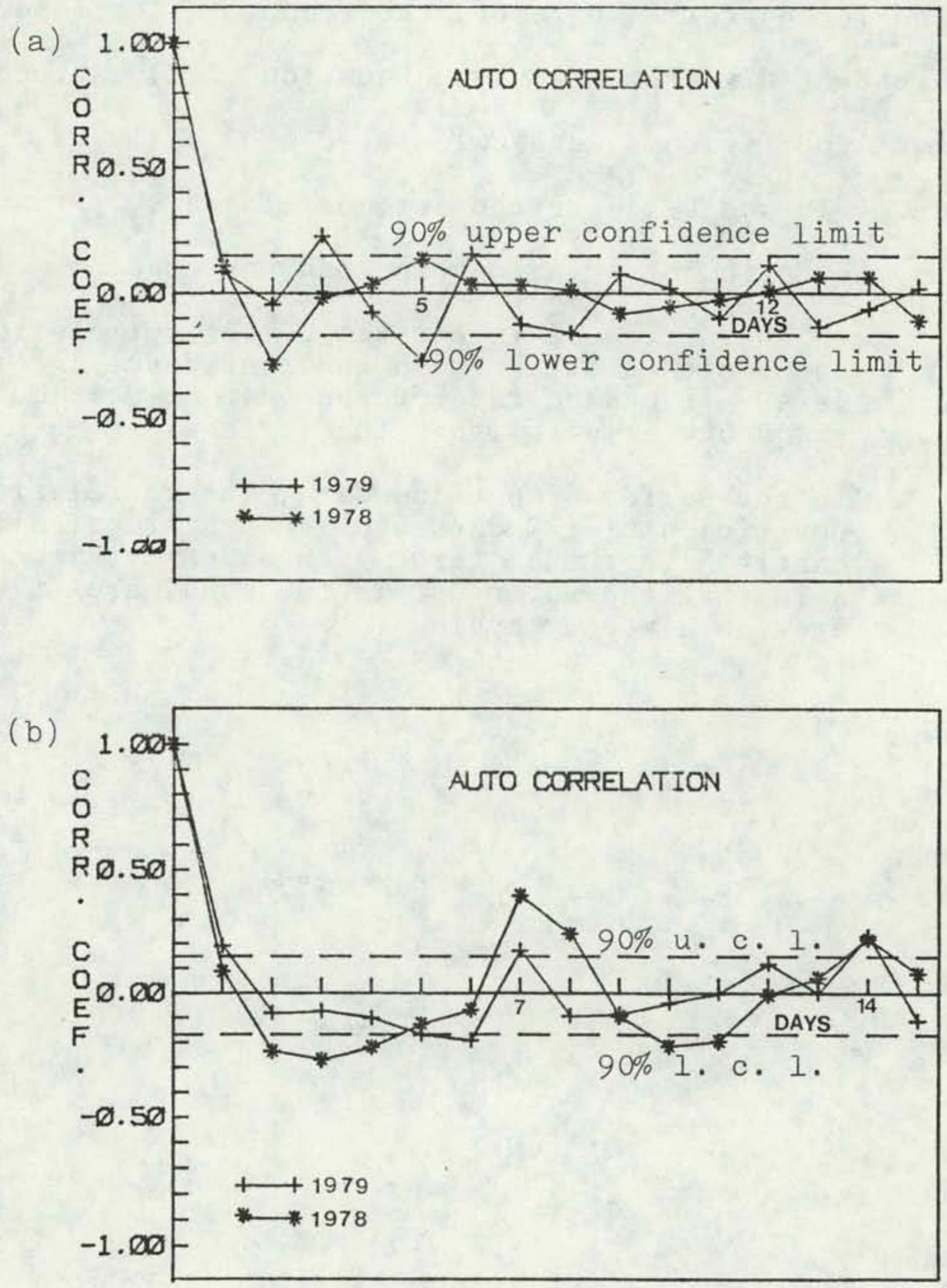


Fig. 4-10.--Autocorrelograms of inflow and outflow in the Idaho Irrigation District. (a) inflow, (b) outflow.

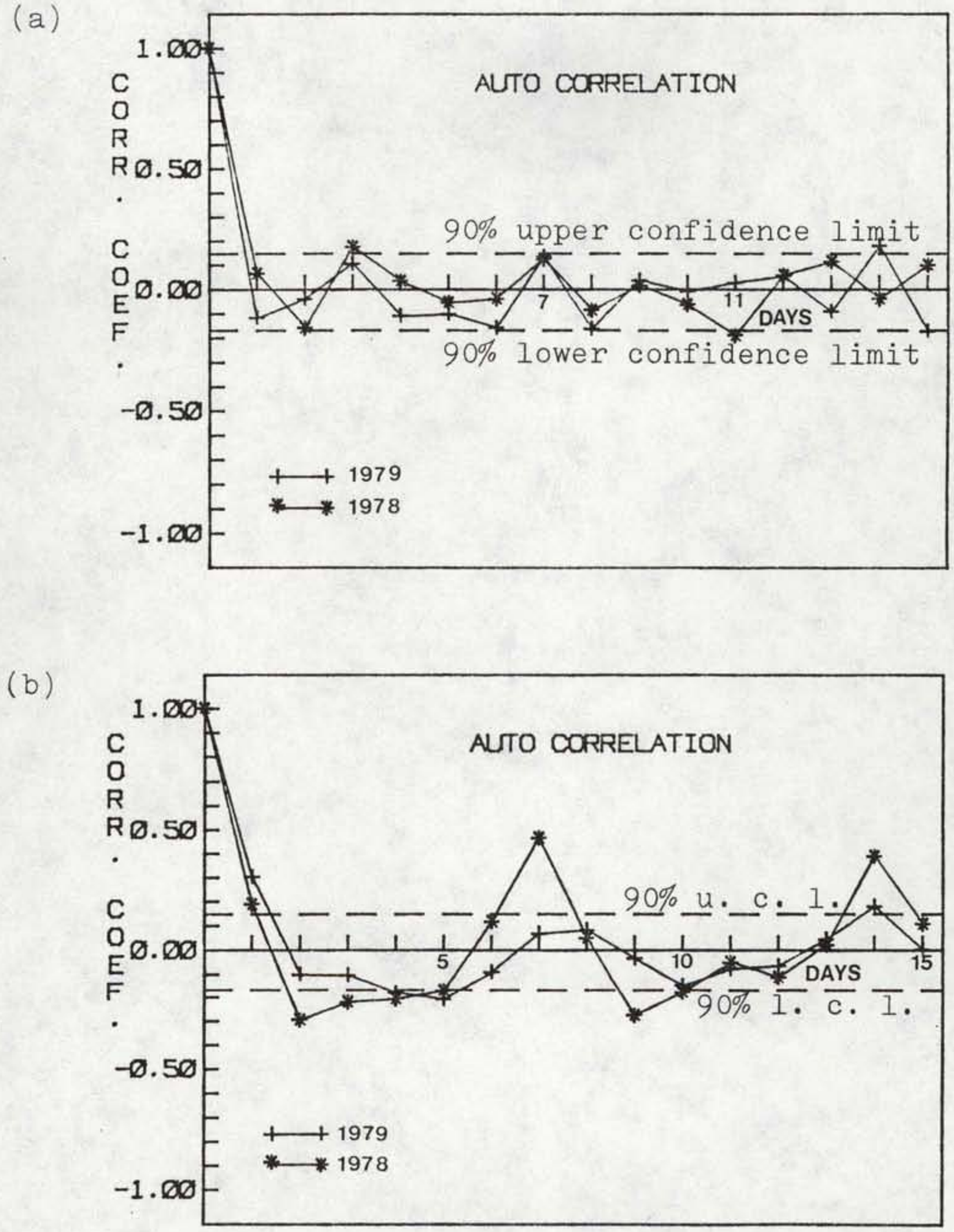


Fig. 4-11.--Autocorrelograms of inflow and outflow in the Snake River Valley Irrigation District. (a) inflow, (b) outflow.

CHAPTER 5

DIVERSION REQUIREMENTS

Water Balance in an Irrigation District

Different approaches to water balance investigations and computations are greatly influenced by a wide variety of physiographical conditions. A generalized water balance equation for an agricultural watershed can be written in the form of the following equation (Fleming, 1975):

$$(P_t - E_t - R_t - G_t - U_t = \Delta S_t)_{time} \qquad (5\text{-}1)$$

where

P_t = total precipitation over the land

E_t = total evapotranspiration from the land

R_t = total surface runoff from the land surface

G_t = total subsurface runoff from the land

U_t = underflow to deep percolation

ΔS_t = change in storage of water in the atmosphere and land

$(\ldots)_{time}$ = a function of time

Fleming stressed that the water balance is a time dependent relationship which must be computed as a continuous function in order to fully understand catchment response.

For analyzing the irrigation process, several water balance models have been proposed. The following equation is fundamental to developing an inflow-outflow water balance for an irrigation district.

$$Q_{in} - Q_{tu} - \Delta S_t = 0 \qquad (5\text{-}2)$$

where

Q_{in} = total inflow and precipitation

Q_{tu} = total water use and outflow

ΔS_t = change in storage with time

The components of Equation (5-2), such as Q_{in}, Q_{tu}, and ΔS_t have been quantified in various degrees to obtain more reliable water balance information for an irrigated area. Kharchenko and Katz (1970) developed an approach to calculate a water balance on an annual basis. Their model considers water movement and variations in three different zones, the surface, subsoil, and ground. The use of this model may result in more accurate water balance, but it requires a great deal of input data.

Claiborn (1975) developed a water balance model to investigate irrigation project efficiency in southern Idaho using the following equation:

$$Q_{rd} + Q_{if} + Q_p - Q_{rf} - Q_{cu} - Q_{csl} - Q_{dpl} = 0 \qquad (5\text{-}3)$$

where

Q_{rd} = river diversion

Q_{if} = supplementary inflow to the district

Q_p = amount of effective precipitation

Q_{rf} = surface return flow

Q_{cu} = consumptive use of crops

Q_{csl} = canal and lateral seepage losses

Q_{dpl} = deep percolation losses

He estimated deep percolation losses using Equation (5-3), then evaluated project efficiency on a bi-weekly basis. He assumed that the net change in soil moisture was negligible as Equation (5-3) does not include a storage term, ΔS_t. Channel and bank storage terms were employed by Tseitlin and Pol'skii (1976) in their water balance model for irrigation canals.

Water Balance Model for Inflow Prediction

Previous investigations have been carried out to establish a water balance itself or to evaluate various irrigation efficiencies on a long-term basis ranging from two weeks to an entire season. Also, due to omitting daily variations in the components of the models, any use of water balance models for predicting inflow has been as a system planning factor.

For more efficient management of an irrigation district, a procedure or modelis needed which is useful in predicting inflow on a daily basis. Being able to predict inflow would allow for better management of the water resource. If it is possible to account for daily variations in the system, daily inflow can be predicted using an inflow-outflow water balance model.

By modifying Equation (5-2), the inflow to an irrigated area can be obtained as:

$$Q_{in} = Q_{tu} + \Delta S_t \qquad (5\text{-}4)$$

Daily variations of the components of Equation (5-4) can be considered to develop relationships between components with respect to time. Equation (5-4) with time elements can be written as:

$$Q_{in}(t_1) = Q_{tu}(t_2) + \Delta S_t(t_3) \qquad (5\text{-}5)$$

where

t_1, t_2, and t_3 = time elements

To predict $Q_{in}(t_1)$ from $Q_{tu}(t_2)$ and $\Delta S_t(t_3)$, it is necessary to have reasonable cause and effect relationships relating the variables. Since these are time dependent variables, it is also important to investigate the relationships among the time variables, such as t_1, t_2, and t_3.

For more practical use, the following equation can be obtained from Equation (5-5).

$$(Q_{in} = E_c + E_t + D_p + S_p + Q_{out} - P_e + \Delta S_t)_{time} \quad (5\text{-}6)$$

where

Q_{in} = total inflow

E_c = evaporation from canals

E_t = evapotranspiration from cropped area

D_p = deep percolation losses from irrigated fields

S_p = seepage losses from conveyance systems

Q_{out} = total outflow

P_e = effective precipitation

ΔS_t = change in water storage within district

$(\ldots)_{time}$ = function of time

$$Q_{in} = Q_{div} + Q_{ex.in}$$

$$Q_{out} = Q_{rt} + Q_{ex.out}$$

where

Q_{div} = inflow at diversion headgate

$Q_{ex.in}$ = inflow from other upstream districts or other land

Q_{rt} = return flow from irrigated fields

$Q_{ex.out}$ = excess water from conveyance system

A schematic diagram of water balance in an irrigation district is shown in Fig. 5-1. The dotted lines depict the return flow or excess water which is wasted into the river directly.

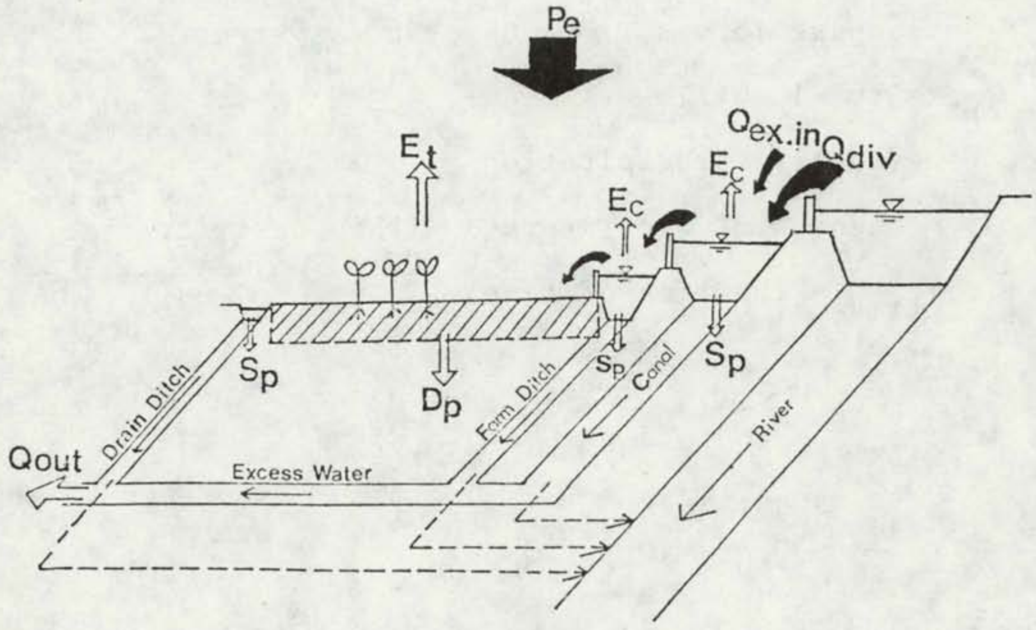


Fig. 5-1.--Schematic diagram of water balance in an irrigation district (symbols are described in Equation 5-6)

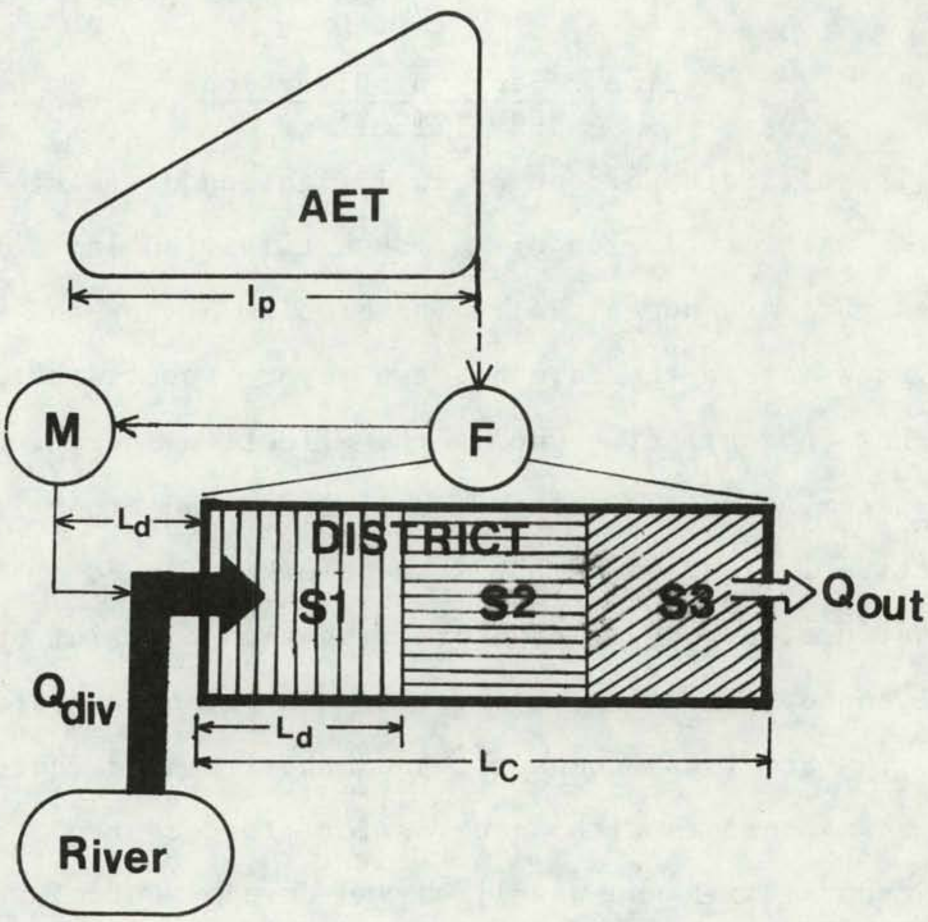
To predict inflow using Equation (5-6), it is important to develop cause and effect relationships among variables, especially the necessary time dependent relationsship.

Time Effects of Diversion Requirements

The ultimate purpose of an irrigation district is to deliver water to irrigators at such times and in such quantities that are beneficial. The problem of how and when to deliver water to the farm has two major aspects that can be somewhat in conflict. One is the effective operation of the system above the point of delivery. The other is the effective irrigation of the farm below it (ASCE, 1980). Furthermore, a general plan of irrigation district operation involves consideration of existing and potential water rights, state laws, compacts, and other related factors, such as agreements with agencies for flood control, conservation of fish and wildlife, and development of recreational facilities.

Determining the proper diversion requirement at the desired time is one of the greatest management problems of an irrigation district. To solve this problem within an irrigation district by being able to predict diversion requirements one or two days in advance would aid district management and provide for more effective use of water.

A simplified irrigation delivery and water use procedure is shown in Fig. 5-2. In an irrigation district



LEGEND.

AET = accumulated evapotranspiration

I_p = irrigation period

M = district manager

F = farmers

L_d = diversion lead time

S_1, S_2, S_3 = subarea

L_c = conveyance time

Fig. 5-2.--Schematic diagram of irrigation procedures with time variables in an irrigation district which uses a demand type of delivery schedule, a farmer first orders water to the manager. The manager then governs the diversion rate to sufficiently supply the water orders.

When a farmer orders water, he has to determine the time and flow rate needed for irrigation. The time and flow rate are strongly related to soil water deficiency which can be estimated from evapotranspiration (E_t) and irrigation period (I_p).

Since a conveyance time (L_c) exists to convey and deliver irrigation water from the diversion point to a field, a diversion lead time (L_d) should be set in advance of field irrigation time. The conveyance time is different depending on the location of each field. Therefore, the diversion lead time should ideally be determined differently for each field or subarea in order to divert the irrigation water required.

However, due to management constraints in an irrigation district and difficulties in determining conveyance time, it is not practical to use a different diversion lead time for particular subareas within a district. Hence, most irrigation districts have used a fixed diversion lead time. The fixed diversion lead time may be greater or less than the actual conveyance time. For example, if the conveyance time from the diversion point to the end of the district is 3 days and the fixed diversion lead time is 1 day, some fields for which the conveyance times are greater than 1 day cannot receive water at the time it is needed. Therefore, it is important to know the irrigation period, diversion lead time and conveyance time, and the relationships among them to relate diversion requirements to water demands.

Consumptive Irrigation Requirement in an Irrigation District

The consumptive irrigation requirement is equal to the net water requirement which is calculated by the difference between E_t and effective precipitation.

The consumptive irrigation requirement from day k to day $k+L_c$ must be predicted to determine the diversion requirement on day k. For example, if a district conveyance time is 3 days, the district can be divided into three different subareas each with the conveyance time for subareas, S_1, S_2, and S_3, being 1 day, 2 days, and 3 days, respectively (Fig. 5-3(a)). Diversion inflow on day k, $Q_{div}(k)$, will be used at S_1 on day k, S_2 on day $k+1$, and S_3 on day $k+2$. The consumptive irrigation requirement for each subarea C_1, C_2, and C_3 (Fig. 5-3(b)), must be calculated based on the day water actually reaches that area.

The irrigation period must be considered in determining the diversion requirement. Optimal irrigation periods can be estimated by considering the application system, soil, crop, and other factors (Khanjani, 1980). The amount of water needed for irrigation can be derived from the soil water deficiency which depends on the irrigation period.

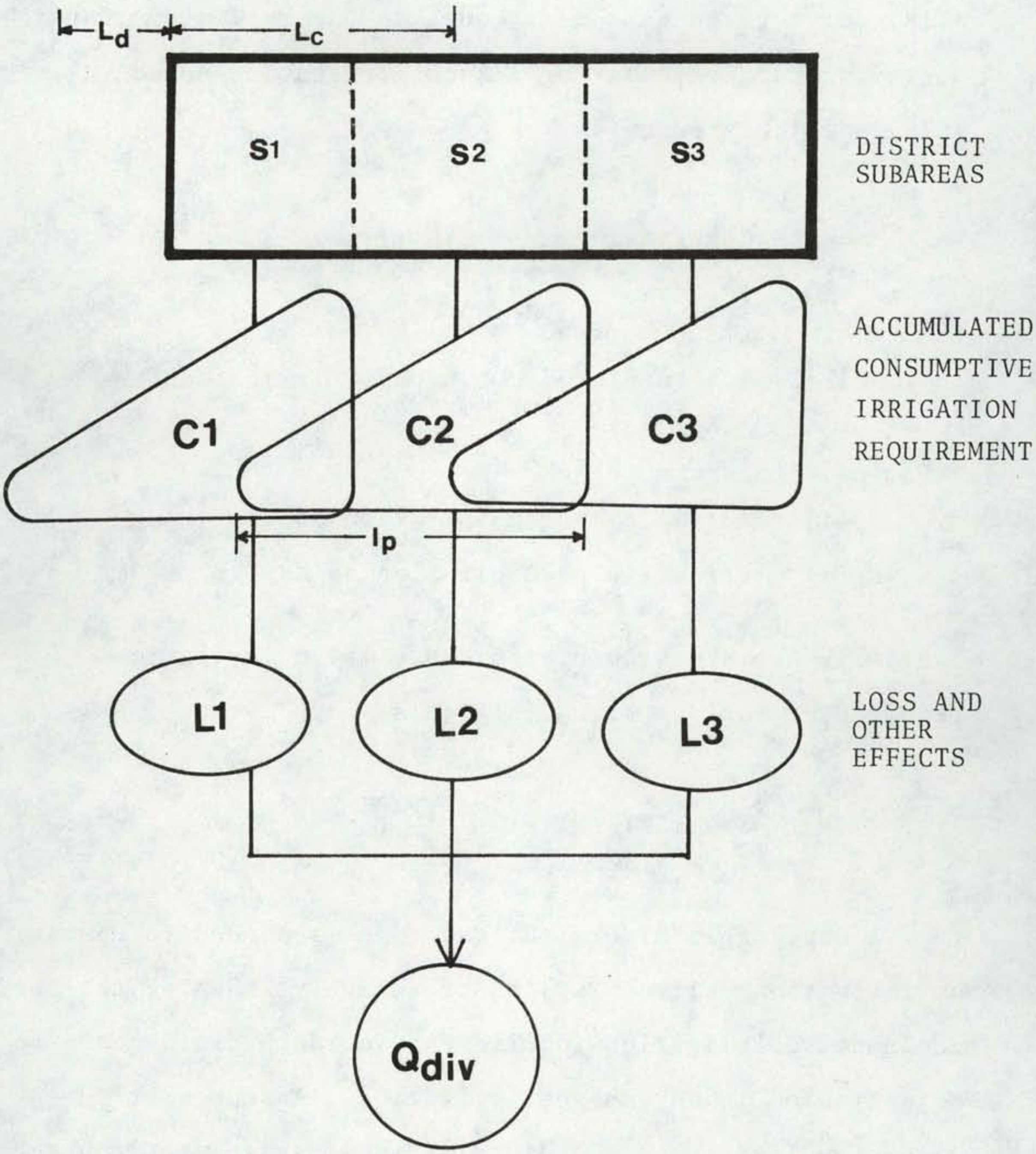


Fig. 5-3.--Schematic diagram for determining diversion requirements

The accumulated consumptive irrigation requirement, ACIR, for a given period is equal to the net water requirement for that period. For a known irrigation period, ACIR is calculated by:

$$ACIR(k) = \sum_{i=k-I_p+1}^{k} (E_t(i) - P_e(i)) \qquad (5-7)$$

where

$ACIR(k)$ = accumulated consumptive irrigation requirement for day k

I_p = irrigation period

$E_t(i)$ = actual evapotranspiration on day i

$P_e(i)$ = effective precipitation on day i

The daily average accumulated consumptive irrigation requirement for day k, DACIR(k), is:

$$DACIR(k) = \frac{ACIR(k)}{I_p} \qquad (5-8)$$

A dependable diversion lead time is needed to operate an irrigation delivery system effectively. Hence, the consumptive irrigation requirement for each field needs to be estimated in advance of irrigation. Assume that the diversion lead time of a district is 1 day and the conveyance time is 3 days to a downstream subarea. The consumptive irrigation requirement of different subareas, such as S_1, S_2, and S_3, have to be estimated at different times due to the required conveyance time. On the average for three subareas, the consumptive irrigation requirement associated with the diversion requirement for day k should be estimated on day k-1 for S_1, on day k for S_2, and on day k+1 for S_3.

The daily consumptive irrigation requirement for an irrigation district as affected by lead and conveyance times and associated with the diversion on day k, $Q_{div}(k)$, is obtained as:

$$Q_c(k,\ k+L_c-1) = \frac{1}{L_c} \sum_{j=k-L_d}^{k-L_d+L_c-1} DACIR(j) \qquad (5\text{-}9)$$

$$= \frac{1}{L_c} \sum_{j=k-L_d}^{k-L_d+L_c-1} \left(\frac{1}{I_p} \sum_{j=k-I_p+1}^{k} (E_t(j) - P_e(j))\right)$$

where

$Q_c(k,\ k+L_c-1)$ = daily consumptive irrigation requirement for the district to be satisfied by $Q_{div}(k)$

L_c = conveyance time

L_d = diversion lead time

Daily Diversion Requirements

The daily diversion requirement on day k can be estimated by adding the daily consumptive irrigation requirement to daily water losses considering other effects (Fig. 5-3). Water losses due to management, seepage, deep percolation, and other effects such as weekly cycle and holidays must also be determined.

CHAPTER 6

PREDICTING DIVERSIONS

Daily water diversions can be determined by the method outlined in Fig. 5-3 and described in Chapter 5. To apply this method to the study districts, the effects of time and water losses must be quantified.

Determining Time Effects

Conveyance Time

The expected outflow from an irrigation district can be estimated from inflow and water use data. Water use includes consumptive irrigation requirements and water losses. The consumptive irrigation requirement is related to the diversion inflow on a specific day and can be estimated using Equation (5-9). The expected outflow can then be estimated using the following equation.

$$Q_{eo}(k) = Q_{div}(k) - Q_c(k,k+L_c-1) - Q_l(k,k+L_c-1) \qquad (6\text{-}1)$$

where

$Q_{eo}(k)$ = expected outflow from $Q_{div}(k)$

$Q_{div}(k)$ = diversion inflow on day k

$Q_c(k,k+L_c-1)$ = consumptive irrigation requirements from $Q_{div}(k)$ (from Equation 5-9)

$Q_l(k,k+L_c-1)$ = water losses from $Q_{div}(k)$

L_c = conveyance time

The expected outflow $Q_{eo}(k)$, represents the amount of water lost from an irrigation district. Since $Q_{eo}(k)$ is derived from $Q_{div}(k)$, the value of $Q_{eo}(k)$ is related to $Q_{div}(k)$. However, the actual outflow $Q_{out}(k+L_c)$ at the downstream end of the district resulting from $Q_{div}(k)$ will occur on day $k+L_c$. The actual outflow, $Q_{out}(k)$, lags behind expected outflow, $Q_{eo}(k)$, by a conveyance time, L_c, as shown in Fig. 6-1.

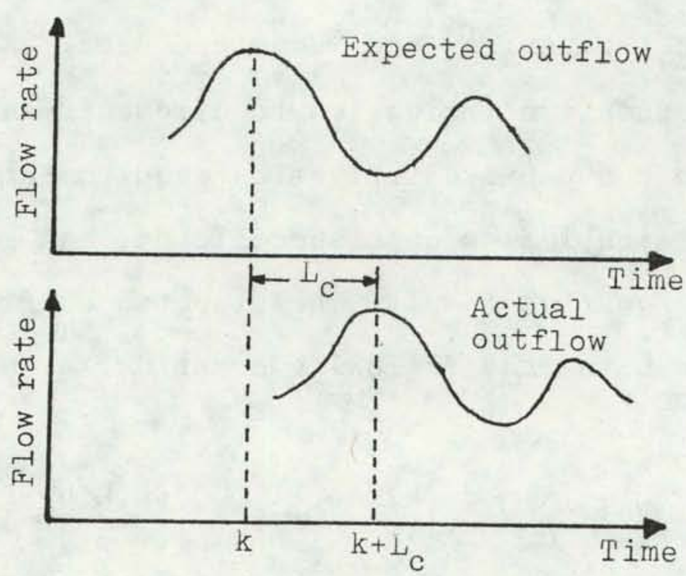


Fig. 6-1.--Lag time between expected outflow and actual outflow

The lag, L_c, that exists between the two series $Q_{eo}(k)$ and $Q_{out}(k)$ can be determined by computing the cross correlation coefficient for the two series. A computer program for calculating lag cross correlation coefficient is listed in Appendix D.

The conveyance time was estimated by the lag cross correlation using Equation (2-8) after removing the trend using Equation (2-7). The lag cross correlation between the actual outflow and expected outflow was estimated for each of three overlapping periods. The duration of each period is 90 days and the starting days are May 16, June 16, and July 16. Lag cross correlation coefficients for each period at the same lag are nearly the same for each district as shown in Fig. 6-2. It can be seen that the conveyance times are nearly the same for each period in the study area.

Significant coefficients exist at a lag of four days for the Idaho Irrigation District, and at a lag of one day for the Snake River Valley Irrigation District. The significant coefficients at lags of 7 and 14 days are due to the weekly cycle effects described in Chapter 4. Hence, the conveyance times can be determined statistically as 4 days for the Idaho Irrigation District and as 1 day for the Snake River Valley Irrigation District.

Irrigation Period

The optimal irrigation periods of the study area were estimated by Khanjani (1980). He estimated the irrigation

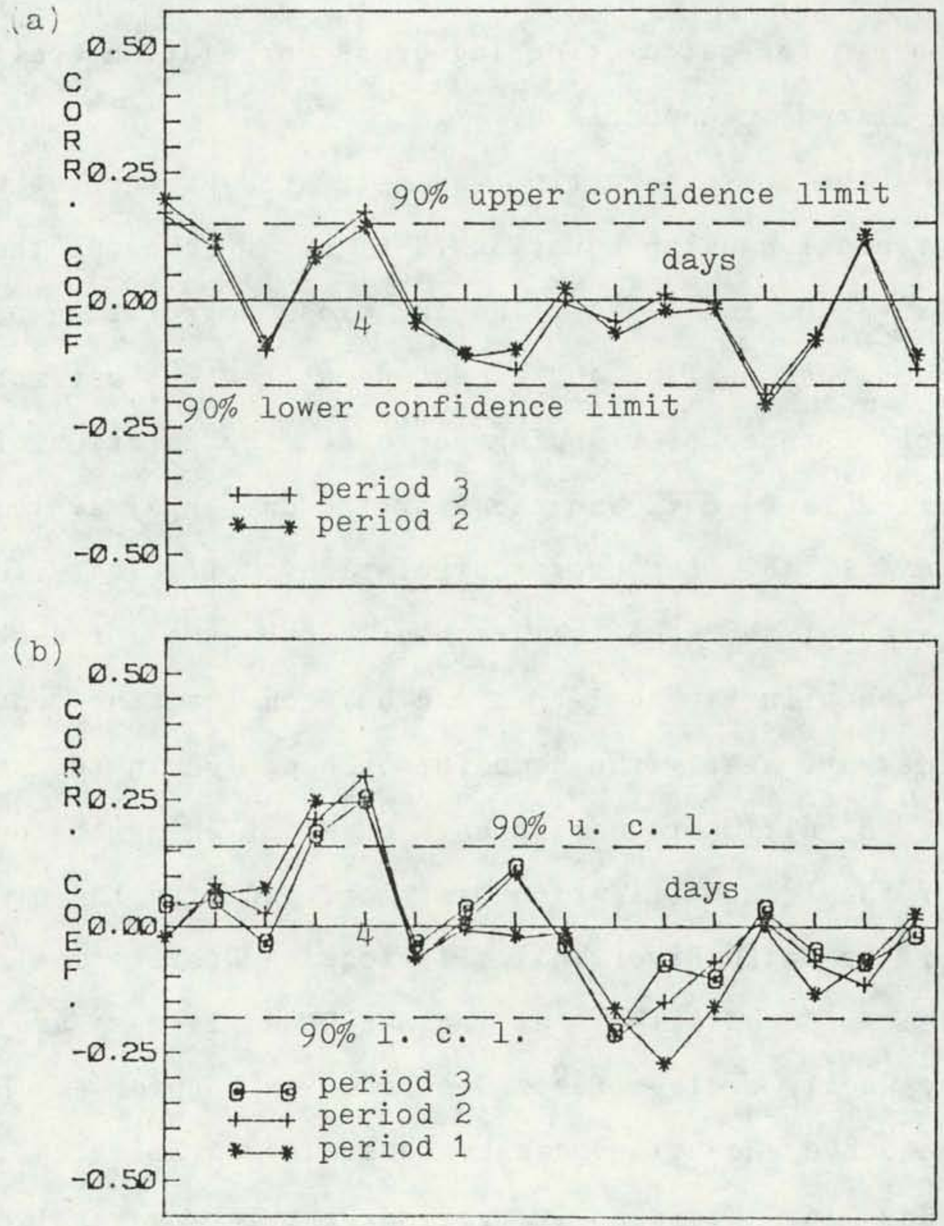
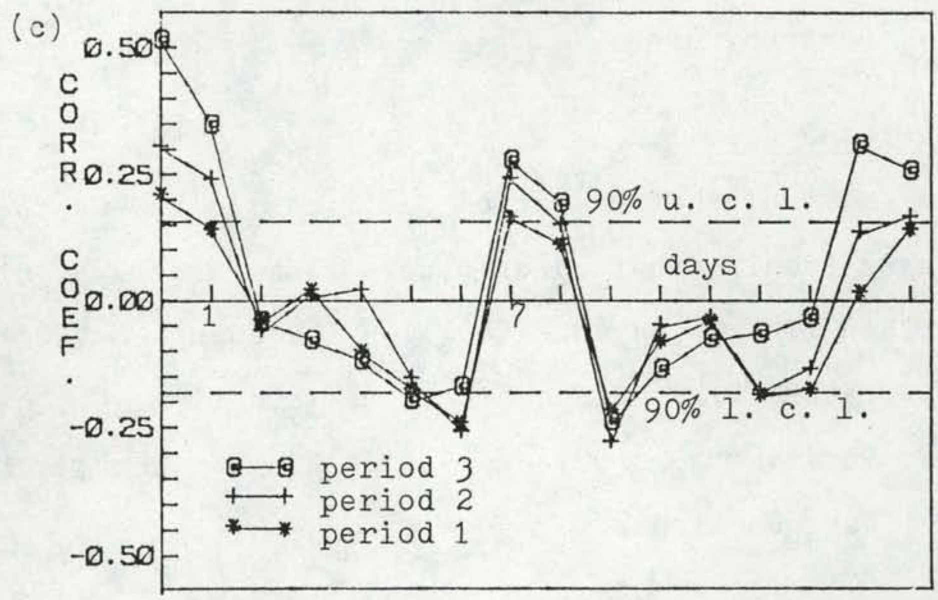


Fig. 6-2.--Lag cross correlograms for the Idaho Irrigation District (IID) and Snake River Valley Irrigation District (SRVID). (a) IID in 1978, (b) IID in 1979. Periods 1, 2, and 3 start May 16, June 16, and July 16, respectively, and each period continues 90 days.



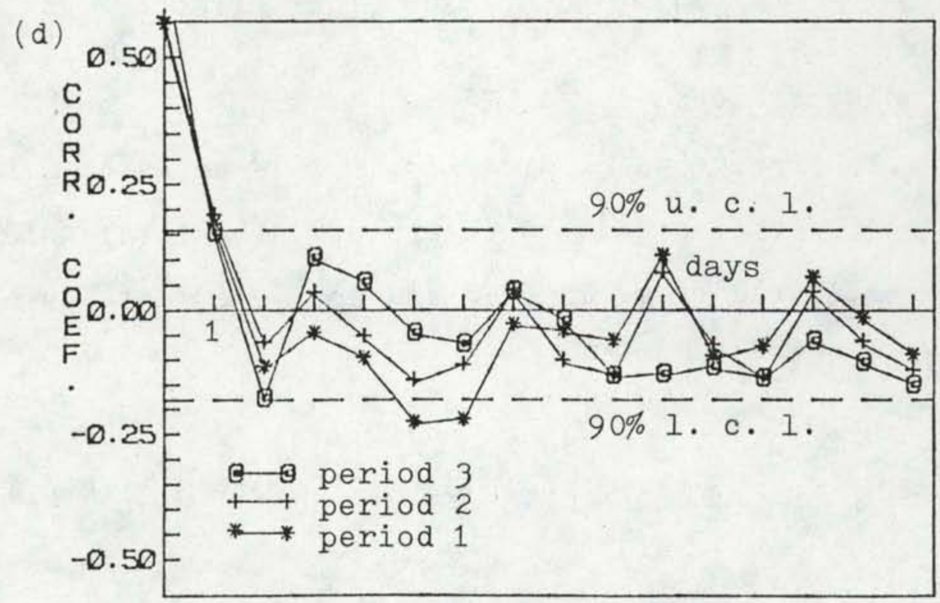


Fig. 6-2.--Continued. (c) SRVID in 1978, (d) SRVID in 1979.

periods for each soil series, cropping pattern, and type of irrigation application systems. Most of the estimated irrigation periods ranged from 4 to 8 days. Therefore, a 6-day period was selected as the average irrigation period for the study area.

Diversion Lead Time

Most of the irrigation districts in the western United States require that water orders from farmers be placed a certain time in advance to allow for adjustment of diversion flow rates. The advance time, or lead time, L_d, used in the districts in the study area is 24 hours. Thus, a lead time of 1 day was assumed.

Water Losses and Other Effects

Total Water Loss

To predict water diversion, it is necessary that water losses be estimated. In this study, the total water loss was estimated from measured and estimated data using Equation (6-2).

$$Q_l(k,k+L_c-1) = Q_{in}(k) - Q_c(k,k+L_c-1) - Q_{out}(k+L_c) \quad (6\text{-}2)$$

where

$Q_l(k,k+L_c-1)$ = total water loss from an irrigation district

$Q_{in}(k)$ = total inflow on day k at the diversion point

$Q_c(k,k+L_c)$ = consumptive irrigation requirement from an irrigation district

$Q_{out}(k+L_c)$ = total outflow at the end of an irrigation district on day $k+L_c$

The total loss includes water losses due to management, seepage, and deep percolation.

The following regression model was considered for predicting the total loss in the study area:

$$Q_1(k,k+L_c-1) = C_0 + C_1 \cdot Q_{in}(k) + C_2 \cdot k \qquad (6\text{-}3)$$

where

C_0, C_1, and C_2 = regression coefficients

k = time variables

Generally, the water-use pattern for a district is different for the first and last parts of an irrigation season. Thus, a multiple linear regression model was applied to the period between May 16 and September 15. Regression coefficients and the correlation coefficients for the total water loss equations are shown in Table 6-1. The regression coefficients of 1978 were used for predicting total water loss.

Other Effects

A significant weekly cycle was found by analyzing the outflows using the autocorrelation method as described in Chapter 4. Thus, weekly effects should be considered in predicting water diversion. In this study, the daily water use coefficients of a week listed in Table 6-2 were assumed to account for weekly effects.

The holidays also affect water use within an irrigation district. However, these were not considered in this study.

Predicting Diversions

Procedure

The procedure for predicting diversion requirements is shown by the flow chart in Fig. 6-3, and a computer program listed in Appendix E was developed by the procedure described as follows:

1. Calculate the consumptive irrigation requirements. For this calculation, actual evapotranspiration, effective precipitation, irrigation period, lead and lag times, and weekly effects are considered (Equation 5-10 and Table 6-2).

2. Assume a diversion requirement. Since the predicted diversion requirement is affected by the assumed value in this model, a reliable value must be supplied as an assumed value.

3. Predict total losses (Equation 6-3 and Table 6-1).

4. Determine the diversion requirement by summing the results of steps 1 and 3.

5. Compare the assumed diversion requirement with the predicted one. If the difference is less than an assumed error limit, accept the predicted value. If not, adjust the assumed value and repeat beginning with step 3.

The input data are:

Table 6-1.--Multiple regression coefficients and correlation coefficients for the total water loss equations

District and year	Regression coefficients: Intercept[1]	Inflow (C_1)	Time[2] (C_2)	Correlation coefficient (R^2)
IID78	125.21	0.88774	-5.61871	0.90
IID79	-410.68	0.83588	-1.84493	0.77
SRVID78	236.75	0.78058	-4.78205	0.63
SRVID79	1329.88	0.28395	-5.19403	0.50

1/ Unit = 1000 m^3/day.

2/ Time variable is the daily sequential order starting from April 1.

Table 6-2.--Assumed daily water use coefficients of a week for the study area

	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Coefficient	0.7	1.2	1.1	1.0	1.0	1.2	0.8

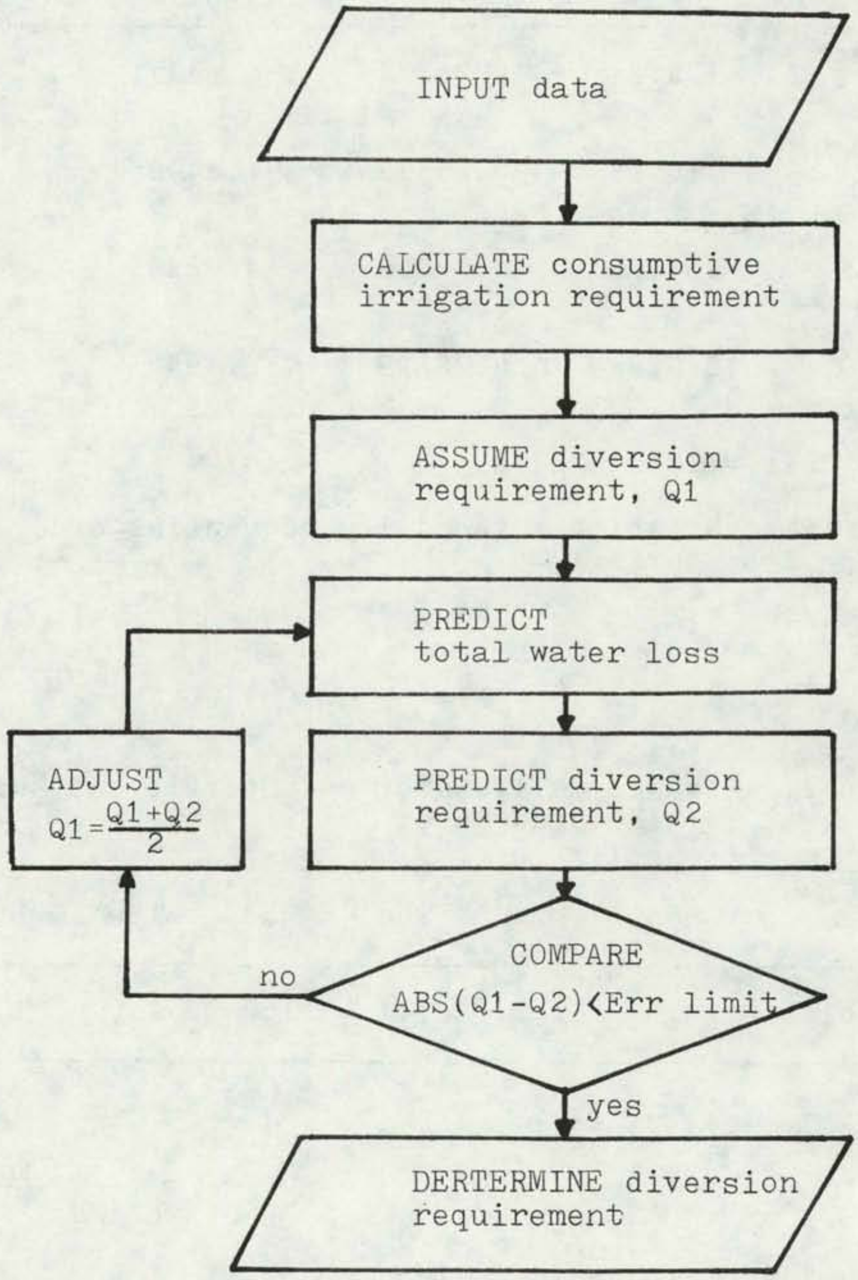


Fig. 6-3.--Flow chart for determining diversion requirements

1. Time effects, such as irrigation period, conveyance time, diversion lead time.

2. Average daily evapotranspiration data for the district and effective precipitation data.

3. Weekly water use coefficients.

4. The minimum outflow from an irrigation district (a constant value).

5. Other data such as size of the district, starting date, total water loss coefficients, and allowed error limit.

In this study, 37,000 m^3/day and 25,000 m^3/day were used as the minimum outflows for the IID and SRVID, respectively, and 12,000 m^3/day was used as the allowed error limit for prediction.

Prediction

The diversion requirements were predicted for the period from May 20 to August 8 in 1978, 1979, and 1980 for the two irrigation districts. The diversion requirements for 1980 were predicted using parameters obtained from the 1978 and 1979 data. The daily predicted diversion requirements and the actual diversions are shown in Figs. 6-4 and 6-5. From these figures, the following observations can be made:

1. The predicted inflows resemble the crop consumptive irrigation requirements more closely than the actual inflows.

2. The predicted inflows have greater fluctuations than the actual inflows.

3. Some of the predicted inflows are greater than the system capacities of the irrigation districts.

4. The predicted inflows are generally higher than the actual inflows for the IID while the predicted inflows for the SRVID were lower than the actual inflows. This implies that it may be possible to more effectively divert the water used in these districts. But it is hard to prove this fact since only two years data were analyzed and used to develop the model parameters.

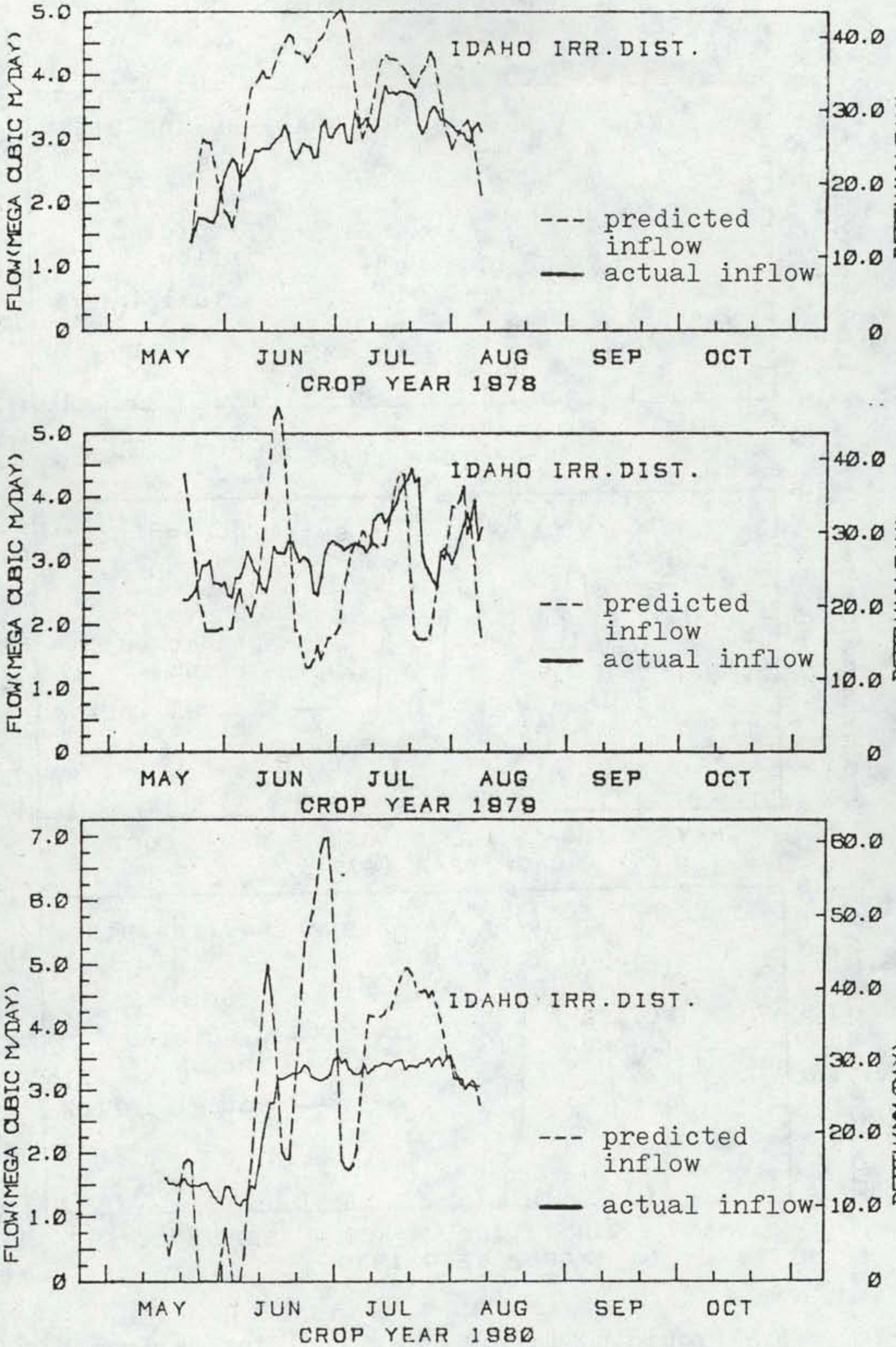


Fig. 6-4.--Predicted inflow and actual inflow from May 20 through August 8 in the Idaho Irrigation District. (a) 1978, (b) 1979, (c) 1980.

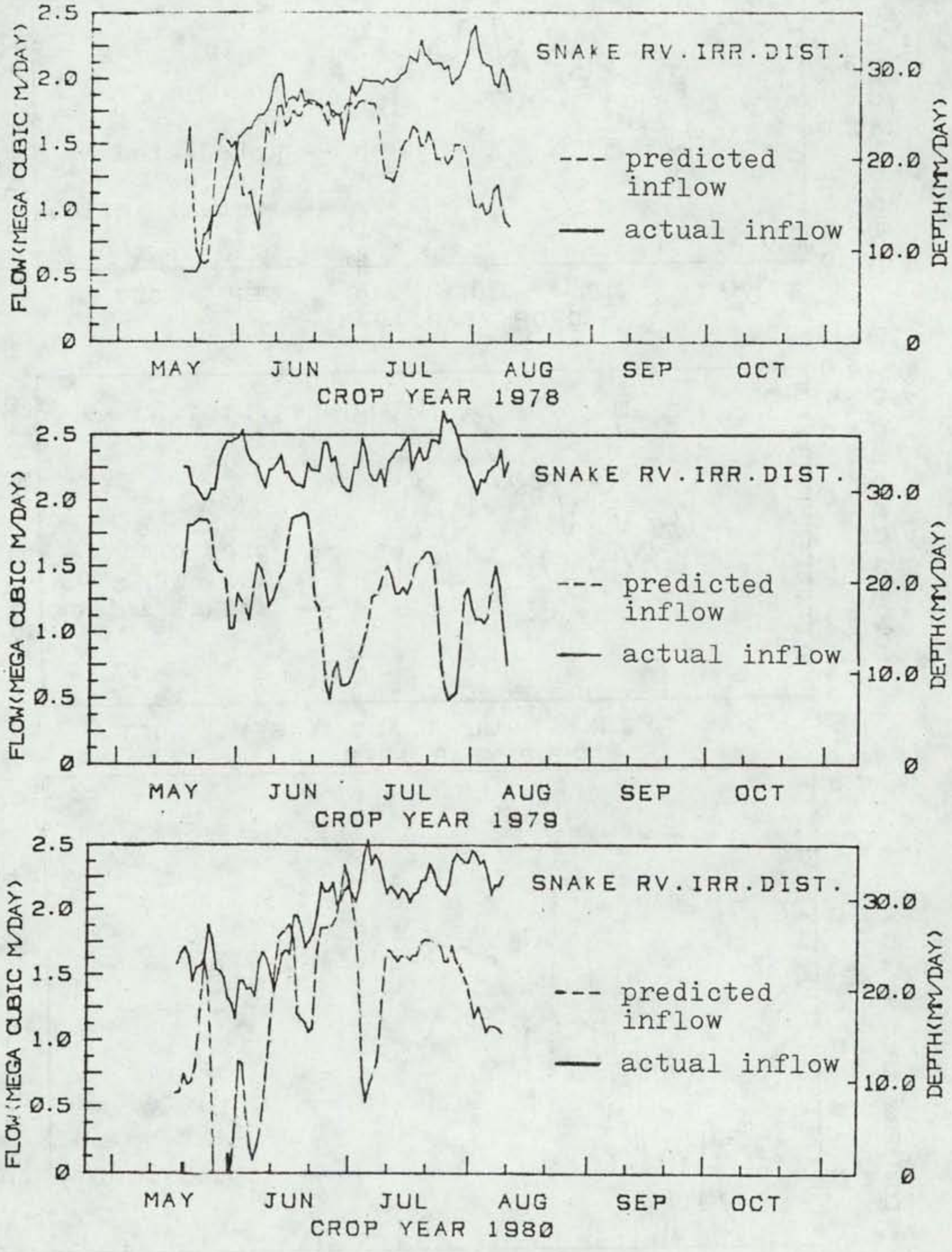


Fig. 6-5.--Predicted inflow and actual inflow from May 20 through August 8 in the Snake River Valley Irrigation District. (a) 1978, (b) 1979, (c) 1980.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

The daily water flow data and crop consumptive water use data for the 1978, 1979, and 1980 irrigation seasons were analyzed to determine the relationships among them for the Idaho Irrigation District (IID) and the Snake River Valley Irrigation District (SRVID). A methodology for predicting daily water diversions was developed for an irrigation district and was applied to the IID and SRVID.

Crop consumptive use estimation varied greatly on a daily basis, and the patterns were quite different from year to year. However, the total consumptive use during the 1978 and 1979 crop growing seasons were nearly the same.

Seasonal irrigation water use amounts were different for different years for the different districts, but the seasonal water use patterns were similar for different years and districts. Total diversion inflow in 1979 was about 10 percent greater than in 1978. Approximately 90 and 80 percent of total inflows were supplied from diversions, and total outflows were about 20 to 27 percent of the total inflows for the IID and SRVID, respectively.

Graphical analysis was used to determine various fluctuations and relations among inflow, outflow, evapotranspiration, and precipitation. Outflow fluctuated more frequently than did inflow. A slight change of evapotranspiration resulted in a rather large change of inflow, and inflow was related to precipitation.

Various relationships among variables were determined by statistical analysis using linear correlation. Generally, negative correlations existed between inflow and outflow, and between outflow and evapotranspiration on the same day. Also a positive correlation existed between inflow and evapotranspiration on the same day.

Autocorrelation was used to determine frequencies within the inflow and outflow of the irrigation districts studied. A weekly cycle was found to exist within outflows, but no significant frequency was found within inflows. Thus, present irrigation schedules of diversions for the IID and SRVID can be adjusted to more precisely meet demand with weekly cycles.

Relationships between time and diversion requirements were established. Based on the time effects, proper consumptive irrigation requirements were estimated at the district level for each of the districts. Multiple linear regression equations were also developed to estimate total water losses due to management, seepage, and deep percolation for the districts studied.

A computer program developed for predicting water diversions for the IID and SRVID did a reasonable job in predicting daily diversions. The predicted values appeared to be more closely related to the consumptive irrigation requirements than the actual inflows. Therefore, the developed method could be used as a beneficial method to save irrigation water. It must be noted that the predicted values need not be close to the actual inflow for the districts. The predicted inflow is the one which the district should divert to meet its requirement effectively if the prediction is correct. However, the actual inflow is what the district diverted, which may or may not be based on actual requirements.

Several recommendations for more effective use of the developed procedure are:

1. More accurate method for predicting water losses would be desirable. It could be obtained by analyzing more reliable data from a long period.

2. As concluded, a weekly cycle exists in outflows. This weekly cycle should be accounted for in a time series model or analyzing farmers' requests for a period.

3. Since some of the predicted inflows were greater than system capacities, a reasonable method should be developed to limit the predicted inflows.

4. Due to the limited amount of data available, the parameters obtained are not applicable to other crop years. More data would be necessary to develop more general parameters for the model.

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APPENDIX A

DAILY DATA FOR INFLOW, OUTFLOW, EVAPOTRANSPIRATION, AND PRECIPITATION IN THE STUDY AREA

Notes:

IID = the Idaho Irrigation District

SRVID = the Snake River Valley Irrigation District

(1) Month Date

(2) Daily inflows of IID in 1978 (1000 m^3/day)

(3) Daily outflows of IID in 1978 (1000 m^3/day)

(4) Daily inflows of IID in 1979 (1000 m^3/day)

(5) Daily outflows of IID in 1979 (1000 m^3/day)

(6) Daily inflows of IID in 1980 (1000 m^3/day)

(7) Daily outflows of IID in 1980 (1000 m^3/day)

(8) Daily inflows of SRVID in 1978 (1000 m^3/day)

(9) Daily outflows of SRVID in 1978 (1000 m^3/day)

(10) Daily inflows of SRVID in 1979 (1000 m^3/day)

(11) Daily outflows of SRVID in 1979 (1000 m^3/day)

(12) Daily inflows of SRVID in 1980 (1000 m^3/day)

(13) Daily outflows of SRVID in 1980 (1000 m^3/day)

(14) Daily evapotranspiration of IID and SRVID in 1978 (mm/day)

(15) Daily evapotranspiration of IID and SRVID in 1979 (mm/day)

(16) Daily evapotranspiration of IID and SRVID in 1980 (mm/day)

(17) Daily precipitation of IID and SRVID in 1978 (mm/day)

(18) Daily precipitation of IID and SRVID in 1979 (mm/day)

(19) Daily precipitation of IID and SRVID in 1980 (mm/day)

"-" indicates no measurement or no estimation.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
401	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.8	2.5	0.0	0.0
402	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.3	2.5	0.5	0.0
403	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	0.0	0.0	0.0
404	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.8	5.1	0.0	0.5
405	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.2	0.0	0.0	0.0
406	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.5	2.5	0.3	0.8
407	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	10.2	0.0	0.3
408	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.3	5.1	0.0	0.0
409	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	0.0	1.8	4.3
410	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6	0.0	0.5	7.1
411	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0	0.0	0.0	0.0
412	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.1	0.0	0.0	0.0
413	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.4	0.0	0.0	0.0
414	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.2	0.0	0.0	0.0
415	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.4	7.6	0.0	0.0
416	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.5	10.2	0.0	0.0
417	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.1	0.0	0.0	0.0
418	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.3	0.0	0.0	0.0
419	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.1	0.0	0.0	0.0
420	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.8	2.5	0.0	0.0
421	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.1	5.1	0.0	0.0
422	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.3	0.0	0.0	0.0
423	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.1	0.0	0.0	0.0
424	-	-	-	-	-	-	-	-	38.2	32.1	32.1	-	-	-	1.7	0.0	0.0	2.0
425	-	-	-	-	-	-	-	-	35.9	31.0	31.0	-	-	-	3.2	0.0	0.0	2.5
426	-	-	-	-	25.7	-	-	-	37.1	28.7	28.7	-	-	-	2.4	7.6	0.0	0.0
427	-	-	-	-	32.8	-	-	-	37.7	30.2	30.2	-	-	-	2.0	0.0	0.0	0.0
428	-	-	-	-	49.2	-	-	-	35.6	14.7	14.7	-	-	-	3.1	0.0	0.0	0.0
429	-	-	-	-	55.3	-	-	-	44.0	34.9	34.9	-	-	-	2.1	2.5	0.0	0.0
430	-	-	-	-	99.3	-	-	-	61.3	44.4	44.4	2.1	-	-	2.2	10.2	0.0	2.5
501	-	-	-	-	78.3	-	-	10.2	510.2	152.8	669.6	0.2	1.4	0.7	2.2	5.1	0.0	0.0
502	-	-	-	-	106.9	-	-	15.4	533.5	297.3	745.9	0.0	2.1	1.4	2.2	0.0	0.0	0.8
503	-	-	-	-	676.9	-	-	43.5	515.3	293.7	755.2	14.7	1.2	0.1	2.6	0.0	0.8	7.4
504	-	-	-	-	787.3	-	401.2	98.1	508.2	255.1	694.4	13.1	1.7	0.4	2.7	0.0	0.0	0.0
505	332.8	-	-	-	1018.2	-	616.5	144.6	516.1	311.8	744.1	9.9	2.0	0.0	3.2	12.7	0.0	0.0
506	665.5	-	-	-	1146.8	-	626.4	161.0	586.1	388.3	827.9	6.3	1.2	0.5	2.2	0.0	0.0	0.0
507	665.5	-	-	-	1238.9	-	621.4	170.7	652.3	335.4	855.2	7.5	1.4	1.3	1.3	0.0	0.0	1.8
508	1130.3	-	-	-	1248.5	-	685.1	147.6	671.1	329.6	840.0	9.5	1.9	1.1	2.0	0.0	0.0	8.6
509	1130.3	-	-	-	1240.9	257.9	1006.5	180.1	703.7	376.5	892.4	11.6	2.9	1.4	1.1	0.0	2.5	2.5
510	1130.3	-	-	-	1433.2	315.1	1207.8	174.9	754.5	357.5	877.5	13.1	2.5	1.7	1.2	5.1	0.0	0.5
511	1096.1	-	-	-	1638.9	462.4	1385.9	260.3	775.4	425.5	927.8	13.4	2.9	2.2	1.4	5.1	0.0	11.2
512	1059.3	-	-	-	1659.3	367.7	1499.0	238.1	782.4	392.9	905.1	12.0	3.2	2.2	2.3	0.0	0.0	0.5
513	1059.3	-	-	-	1993.9	401.2	1692.6	144.8	786.0	347.6	856.0	12.1	3.2	2.1	2.8	0.0	0.0	0.0
514	1059.3	-	264.2	-	2013.3	544.1	1740.7	163.9	771.8	302.4	789.9	102.1	3.4	3.1	3.7	0.0	1.8	0.0
515	1059.3	-	525.9	-	1882.6	438.4	1950.1	249.0	776.0	282.8	732.1	69.1	2.6	3.4	1.6	0.0	0.0	2.5
516	1059.3	-	525.9	-	2009.1	484.9	2256.7	511.0	813.1	421.5	798.2	60.8	1.4	2.4	1.4	0.0	0.0	14.5
517	1370.0	-	525.9	-	2279.4	587.4	2248.9	583.6	766.8	496.2	839.2	134.1	1.2	3.2	1.8	10.2	0.0	2.0
518	1370.0	-	525.9	-	2427.7	406.9	2113.0	393.8	768.8	503.7	863.7	173.4	0.9	3.3	1.9	10.2	0.0	2.8
519	1370.0	-	525.9	-	2386.1	391.0	2093.1	245.8	750.6	455.1	827.0	242.7	2.4	3.5	3.6	0.0	0.0	0.0
520	1370.0	-	577.4	-	2391.9	366.2	2045.8	239.8	774.5	349.3	729.7	379.3	2.6	4.1	3.9	0.0	0.0	0.0
521	1370.0	-	807.3	-	2383.4	305.3	1995.1	263.0	810.1	391.4	783.7	355.9	3.7	3.8	4.0	0.0	0.0	0.0
522	1397.0	-	836.7	-	2444.1	165.2	1992.2	149.0	763.1	356.2	791.4	348.2	2.0	3.8	1.6	0.0	0.0	1.3
523	1575.6	-	949.3	-	2522.2	181.8	2075.7	148.3	742.5	367.0	817.4	368.6	2.0	4.0	1.5	0.0	0.0	0.5

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(19)	(19)
524	1771.3	-	954.2	-	2707.8	175.6	2071.2	263.0	754.1	576.8	952.1	556.0	2.3	3.2	2.2	2.5	12.2	10.7
525	1756.6	-	1027.6	-	2929.7	454.3	2295.1	520.2	745.8	613.0	898.8	641.2	2.2	4.0	1.9	0.0	0.0	13.2
526	1732.2	-	1076.4	-	2950.8	532.9	2375.7	405.2	764.6	565.9	783.0	529.3	2.7	3.0	2.2	0.0	0.0	14.5
527	1695.4	-	1169.4	-	3014.3	634.6	2441.4	477.1	775.0	545.3	773.1	511.0	3.0	4.3	3.0	0.0	0.0	0.0
528	1671.0	-	1264.9	-	2662.3	576.4	2441.6	472.9	714.3	494.1	749.1	477.0	2.9	2.4	2.8	0.0	2.3	0.0
529	1800.6	-	1357.8	-	2648.1	612.2	2461.0	512.3	655.7	391.3	666.9	396.6	2.7	3.7	2.3	0.0	2.1	0.5
530	2175.0	-	1568.2	-	2609.0	730.3	2474.9	572.5	612.3	356.1	647.2	380.2	2.5	1.6	2.9	10.2	0.0	3.8
531	2405.0	-	1597.6	-	2659.3	798.3	2534.6	535.8	593.7	276.9	597.4	330.4	3.3	4.7	2.6	0.0	0.0	1.5
601	2568.8	-	1636.7	-	2458.3	624.6	2383.2	414.0	736.1	443.4	734.4	417.8	4.0	1.2	2.8	0.0	0.0	3.0
602	2691.2	-	1631.9	-	2423.3	530.6	2306.6	302.0	743.8	474.3	738.5	485.4	2.9	0.8	2.4	0.0	0.0	5.9
603	2617.8	-	1695.4	-	2739.9	534.3	2279.7	251.8	666.4	404.1	703.2	491.8	2.6	5.0	1.9	5.1	0.0	1.8
604	2378.0	-	1739.4	-	2751.9	430.6	2242.3	311.9	599.3	367.4	710.0	458.5	4.2	2.8	1.6	0.0	0.0	5.6
605	2422.0	-	1744.4	-	2906.0	296.8	2145.6	318.2	579.6	356.1	675.7	423.7	5.2	3.5	2.6	0.0	0.0	0.5
606	2520.0	-	1773.7	-	3171.0	314.9	2082.0	381.9	626.4	502.0	808.7	432.2	5.2	3.3	3.2	0.0	0.0	0.0
607	2642.2	-	1837.4	-	3032.0	617.5	2222.9	694.1	636.1	554.7	849.7	507.3	3.7	1.4	3.8	0.0	5.1	0.0
608	2838.0	-	1993.9	-	2858.1	751.8	2228.0	809.8	744.4	536.1	826.3	482.0	4.6	4.2	4.1	0.0	0.0	0.0
609	2813.5	-	2060.0	-	2778.3	592.1	2270.7	628.3	721.3	478.1	766.2	473.3	4.3	4.5	5.1	0.0	0.0	0.0
610	2862.5	-	2060.0	-	2572.5	690.6	2336.2	663.5	899.3	363.4	698.1	436.6	2.7	6.1	5.8	2.5	0.0	0.0
611	2862.5	-	1803.1	-	2514.5	411.7	2201.1	410.5	1122.7	364.7	765.9	299.1	4.1	5.5	5.6	0.0	0.0	0.0
612	2862.5	-	1871.7	-	2755.6	363.0	2213.8	295.8	1288.5	408.4	844.3	316.3	6.5	8.0	6.4	0.0	0.0	0.0
613	2960.3	-	1886.3	-	3231.2	264.0	2143.1	197.0	1408.9	304.8	660.0	307.6	4.9	4.4	6.9	0.0	0.0	0.0
614	3033.7	-	1852.0	-	3136.2	152.7	2108.5	195.5	1407.6	277.0	846.0	326.3	5.8	5.9	4.5	0.0	0.0	0.0
615	3082.7	-	1947.4	197.0	3122.8	149.5	2099.8	212.2	1607.2	327.7	996.3	273.6	5.3	6.2	0.9	0.0	0.0	13.5
616	3253.9	-	1852.0	299.0	3123.5	183.8	2080.5	246.3	1602.3	338.2	995.2	277.4	3.9	6.7	5.2	0.0	0.0	1.8
617	3131.5	-	1861.6	421.6	3306.3	477.8	2272.5	398.5	1618.2	243.0	948.0	275.3	4.3	5.1	5.9	0.0	0.0	0.0
618	2836.0	-	1857.0	414.2	3309.6	563.2	2220.2	465.1	1637.1	182.9	869.2	126.8	5.7	2.5	6.4	0.0	4.6	0.0
619	2715.7	-	1837.4	401.5	3133.7	730.6	2211.7	427.4	1656.4	226.5	895.9	140.2	4.7	4.6	6.4	0.0	3.1	0.8
620	2813.5	-	1803.1	273.1	2986.0	840.4	2203.8	513.0	1650.7	214.4	924.2	139.5	5.9	5.2	7.0	0.0	0.0	0.0
621	2960.3	-	1808.0	332.3	3056.0	1103.1	2420.6	775.8	1670.5	249.5	999.4	181.6	6.0	0.8	7.1	2.5	1.8	0.0
622	2911.3	-	1842.3	326.6	3023.5	1207.3	2433.6	920.2	1721.3	405.8	1126.6	278.1	6.3	3.7	7.4	0.0	1.5	0.0
623	2886.9	-	1724.8	298.0	2915.3	945.5	2278.0	730.1	1703.2	352.0	1089.9	273.3	5.1	0.5	6.8	0.0	0.0	0.0
624	2728.4	-	1749.3	333.9	2483.0	1108.0	2314.2	812.0	1624.2	279.4	1091.9	223.1	5.0	1.9	6.3	0.0	0.0	0.0
625	2744.6	-	1749.3	511.5	2443.6	852.6	2166.9	632.6	1604.6	226.3	1127.1	170.7	6.2	2.9	8.7	0.0	0.0	0.0
626	3232.4	-	1558.5	606.5	2713.0	545.6	2083.0	373.4	1589.2	171.2	1038.5	103.9	5.5	1.3	9.8	0.0	0.0	0.0
627	3331.0	81.3	1703.3	512.3	3113.5	390.0	2050.4	294.8	1595.0	150.5	1057.4	103.1	6.4	2.4	10.8	0.0	0.0	0.0
628	3063.8	191.6	1967.7	333.2	3263.3	415.4	2038.2	283.6	1615.0	202.0	1099.5	76.6	6.3	1.9	7.9	0.0	0.0	0.0
629	3047.1	132.8	1901.8	270.1	3307.3	628.3	2221.5	494.2	1640.3	229.3	1114.6	114.5	6.1	5.4	6.2	0.0	0.0	0.0
630	3183.0	128.2	1941.1	212.4	3262.5	635.6	2222.5	763.3	1765.5	156.0	1084.0	114.0	8.3	1.8	3.8	0.0	0.0	0.0
701	3262.5	178.6	2020.8	350.3	3221.6	718.0	2445.3	1088.4	1787.2	78.0	1051.0	110.8	5.4	6.0	4.3	0.0	0.0	5.3
702	3287.7	173.4	2010.8	517.9	3149.7	623.9	2344.6	854.3	1736.5	219.6	1118.1	116.7	4.8	5.2	4.7	0.0	0.0	12.7
703	2993.9	194.5	2007.3	516.7	3193.4	505.5	2173.0	609.5	1764.3	380.0	1234.3	171.5	5.5	6.0	5.9	0.0	0.0	0.0
704	2971.3	210.4	1998.8	356.0	3241.9	507.4	2124.3	443.3	1684.7	451.7	1298.5	259.2	4.9	4.5	6.5	0.0	0.0	0.0
705	3493.2	216.0	2001.5	513.0	3268.8	405.2	2116.3	285.1	1647.4	475.7	1200.0	274.4	5.2	4.3	10.6	0.0	0.0	0.0
706	3219.6	82.9	1980.7	364.7	3229.9	461.4	2202.6	303.8	1635.1	488.2	1238.9	279.7	4.8	6.3	7.8	2.5	0.0	0.0
707	3274.2	128.9	2025.0	268.6	3205.6	346.7	2074.7	371.9	1647.2	448.4	1216.3	220.9	5.1	5.5	3.1	0.0	0.0	0.5
708	3377.2	207.2	2000.8	358.0	3112.0	425.6	2267.7	435.0	1721.8	400.3	1146.8	132.4	5.3	5.3	5.6	0.0	0.0	0.0
709	3254.4	282.1	1992.4	392.4	3202.1	409.8	2303.9	390.8	1650.3	348.1	1083.8	95.5	5.8	6.6	7.7	0.0	0.0	0.0
710	3149.2	231.4	2017.2	381.6	3623.3	411.7	2359.5	351.5	1680.7	298.9	1111.6	114.6	7.4	3.3	6.9	0.0	0.0	0.0
711	3233.2	222.9	2059.0	279.1	3705.1	402.5	2360.2	356.7	1712.7	200.1	1051.1	134.4	7.2	6.0	6.9	0.0	0.0	0.0
712	3516.3	131.4	2074.7	218.9	3740.2	391.7	2406.6	341.8	1719.0	140.1	1064.5	101.6	6.6	6.4	6.9	0.0	0.0	0.0
713	3879.5	245.6	2197.9	247.6	3589.1	386.1	2473.0	37.6	1737.3	197.2	1099.8	114.3	5.6	6.0	7.9	0.0	0.0	0.0
714	3753.2	218.9	2174.2	233.6	3670.0	295.5	2212.7	295.0	1731.9	150.9	1085.7	123.3	7.1	7.2	5.8	0.0	0.0	2.0
715	3770.6	247.8	2154.9	218.4	3789.9	417.2	2306.3	354.5	1714.3	92.0	1048.0	85.8	4.0	7.6	5.1	0.0	0.0	0.0

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
716	3735.2	363.0	2315.0	553.5	3892.4	382.1	2381.2	307.5	1749.9	90.7	1081.1	84.9	6.9	7.6	8.1	0.0	0.0	0.0
717	3781.4	313.9	2206.5	539.3	4101.4	170.2	2286.6	200.6	1762.7	89.7	1068.7	96.3	7.1	6.6	8.3	0.0	0.0	0.0
718	3783.8	234.9	2175.0	360.9	4202.7	168.6	2306.8	212.9	1768.9	170.3	1134.9	114.1	7.8	6.7	8.3	0.0	0.0	0.0
719	3751.1	191.6	2130.9	355.0	4292.0	233.9	2445.6	267.4	1685.9	152.9	1140.0	123.2	5.5	5.8	7.5	0.0	0.0	0.0
720	3730.7	204.3	2145.4	338.6	4463.7	296.3	2438.4	341.8	1719.0	222.1	1206.7	168.7	5.1	6.8	6.9	0.0	0.0	0.0
721	3641.9	421.4	2144.4	556.3	4247.4	337.8	2412.8	344.0	1715.5	186.6	1175.2	187.9	5.8	6.2	7.0	0.0	0.0	0.0
722	3245.1	498.6	2096.4	679.6	4302.0	951.7	2655.0	772.4	1701.6	128.4	1117.9	114.0	7.1	2.5	7.2	0.0	12.4	0.0
723	3092.4	602.1	2117.7	795.6	3108.3	1160.4	2571.3	1213.7	1736.8	136.5	1096.9	103.2	7.4	7.4	8.5	0.0	0.0	0.0
724	3206.1	347.2	1978.5	549.8	2900.6	962.0	2589.4	1125.4	1741.7	123.2	1082.9	62.3	8.0	6.5	6.8	0.0	0.0	0.0
725	3456.7	248.3	2016.0	219.4	2792.9	742.3	2530.9	898.6	1776.9	152.0	1117.4	41.1	7.6	6.8	8.3	0.0	0.0	0.0
726	3546.2	206.2	2042.9	189.1	2662.3	653.2	2448.8	680.6	1711.2	251.4	1217.6	125.2	7.3	7.1	7.6	0.0	0.0	0.0
727	3463.3	195.5	2123.2	237.6	2565.2	505.5	2313.5	461.4	1766.0	297.9	1243.6	234.1	7.0	8.0	6.5	0.0	0.0	0.0
728	3324.3	324.4	2205.8	399.0	3080.5	557.5	2275.2	506.5	1790.6	279.9	1226.3	252.4	2.5	5.2	8.8	0.0	0.0	0.0
729	3315.8	457.2	2381.2	609.2	3020.8	609.2	2174.2	524.6	1715.5	219.6	1210.0	216.1	4.8	4.2	6.4	0.0	0.0	2.0
730	3265.3	720.2	2437.0	882.4	3396.6	420.6	2111.1	355.7	1774.3	256.3	1206.7	186.6	6.8	7.2	7.2	0.0	0.0	0.0
731	3207.4	643.9	2250.3	715.4	3846.7	162.7	2010.5	181.1	1801.1	307.0	1253.3	191.8	7.3	7.0	5.9	0.0	0.0	0.0
801	3128.2	440.8	2156.8	551.5	3855.3	296.5	2121.2	235.6	1723.9	352.4	1238.3	196.9	6.9	6.7	5.8	0.0	0.0	0.5
802	3087.7	545.1	2367.0	471.7	3960.4	236.1	2103.5	220.4	1627.1	393.7	1203.4	256.3	7.1	7.3	10.5	0.0	0.0	0.0
803	3095.6	394.1	2195.6	483.1	4170.1	422.2	2188.7	318.2	1561.9	419.4	1216.4	360.7	6.7	9.9	6.7	0.0	0.0	0.0
804	2987.0	364.6	2086.7	481.7	3422.7	618.2	2220.0	589.8	1533.1	399.5	1159.2	424.6	6.9	8.2	6.4	0.0	0.0	0.0
805	2935.9	372.6	2055.8	478.8	3650.7	756.5	2239.4	719.2	1553.1	318.6	1078.7	311.3	5.6	6.6	7.1	0.0	0.0	0.0
806	3179.0	663.5	2234.7	747.2	3952.9	807.5	2352.1	906.5	1592.0	380.9	1118.4	499.7	4.8	5.0	6.2	0.0	0.0	0.0
807	3248.1	708.7	2260.8	913.0	3324.3	552.2	2146.8	558.0	1547.1	388.3	1113.9	403.8	5.1	1.7	6.1	0.0	0.0	0.0
808	3110.3	530.9	2091.8	611.2	3520.6	689.6	2251.3	698.5	1542.9	463.5	1150.5	463.2	5.0	3.9	6.6	0.0	1.0	0.0
809	3088.5	459.5	2022.6	567.9	3771.6	828.1	2444.1	1052.5	1360.9	431.2	1106.0	456.1	5.9	5.8	6.7	0.0	0.0	0.0
810	3065.0	603.8	2124.8	718.5	3212.6	728.1	2322.0	950.8	1375.7	470.8	1120.6	425.9	4.1	5.1	5.0	0.0	0.0	0.0
811	3012.4	808.2	2276.1	907.0	2873.5	668.4	2174.0	960.5	1356.2	468.0	1138.1	525.9	5.4	0.0	6.7	0.0	0.0	0.0
812	2930.0	828.6	2273.5	1059.3	3043.7	990.8	2363.8	1304.3	1298.6	305.4	1038.9	399.8	3.8	2.2	6.1	5.1	2.8	0.0
813	3221.8	1032.4	2382.4	1519.3	2661.3	1284.7	2335.7	1535.9	1271.3	252.0	972.1	273.5	2.4	1.9	5.0	0.0	14.2	0.0
814	2976.2	1017.4	2306.7	1552.3	2167.9	1137.9	2264.5	1552.1	1267.0	265.7	995.0	319.5	2.8	3.7	4.3	0.0	4.1	1.0
815	2579.4	822.4	1991.8	971.0	2127.2	1121.5	2375.8	1444.9	1370.1	374.8	1058.2	439.7	6.0	4.0	2.8	0.0	0.0	15.7
816	2579.2	788.8	1939.9	838.6	1951.8	1034.6	2011.5	1198.1	1271.9	460.1	987.3	669.8	0.0	3.7	5.4	7.6	0.0	3.3
817	2275.0	692.8	1825.2	861.9	1823.4	949.8	1934.2	997.3	1282.2	563.3	1065.2	680.0	2.7	2.9	2.6	0.0	0.0	0.8
818	2313.0	677.9	1835.6	922.6	1745.8	759.9	1777.7	836.7	1334.2	535.0	1062.1	705.8	3.9	3.3	1.3	0.0	0.0	0.0
819	2308.6	712.2	1805.8	903.0	1819.0	831.6	1797.3	858.2	1060.5	569.9	978.0	624.9	4.5	2.3	1.5	0.0	0.0	15.2
820	2335.4	694.1	1656.5	859.5	1869.7	813.2	1842.8	888.1	834.6	509.7	915.2	613.9	4.2	3.7	3.4	0.0	6.3	0.3
821	2214.8	679.6	1627.2	717.6	1824.7	748.3	1802.8	738.1	834.1	371.4	844.6	496.6	2.9	4.0	4.8	0.0	0.3	0.0
822	2034.6	501.9	1516.2	541.9	1826.6	733.9	1811.7	626.4	818.0	353.4	838.0	522.0	1.6	4.0	4.4	0.0	0.0	0.0
823	2259.3	445.8	1513.2	564.9	1720.7	632.9	1764.2	544.6	843.8	350.1	876.6	495.4	4.0	3.3	4.7	0.0	0.0	0.0
824	2336.9	589.3	1675.7	637.6	1771.5	595.3	1775.7	504.7	862.3	373.2	848.1	411.6	4.8	3.9	5.1	0.0	0.0	0.0
825	2287.7	586.1	1750.7	636.8	1904.3	509.4	1777.7	495.7	824.7	279.4	761.5	417.3	4.4	4.7	2.7	0.0	0.0	0.0
826	2193.8	531.9	1722.4	548.0	2102.3	597.2	1824.7	522.6	1009.5	272.1	765.9	435.0	3.1	2.2	2.9	0.0	0.0	0.0
827	2239.8	600.3	1803.1	640.8	2236.4	717.8	1882.9	553.5	1004.7	273.6	840.1	383.9	2.3	1.7	2.3	0.0	0.0	0.8
828	2209.0	515.7	1851.3	647.3	2293.4	687.0	1882.4	524.1	1029.7	273.8	844.9	312.6	2.4	2.5	2.6	0.0	0.0	0.0
829	2262.5	387.3	1724.5	524.6	2314.7	603.0	1778.2	393.6	1028.6	293.7	854.1	332.7	2.4	2.4	2.9	0.0	0.0	0.0
830	2360.2	412.2	1715.0	485.1	2249.8	455.8	1673.2	310.2	1026.4	259.4	839.0	273.1	1.8	2.7	2.1	0.0	0.0	0.0
831	2400.6	375.6	1727.0	477.6	2250.8	528.7	1626.0	322.7	1053.3	264.7	837.2	251.5	2.1	2.4	2.0	0.0	0.0	1.8
901	2379.2	428.4	1821.2	502.8	2298.8	581.3	1646.1	355.2	1066.6	242.3	827.8	233.5	2.4	2.8	2.3	0.0	0.0	0.0
902	2423.3	386.8	1801.8	473.7	2245.4	549.0	1609.1	358.2	1129.0	236.7	825.1	189.6	2.8	2.5	4.2	0.0	0.0	0.0
903	2510.8	471.2	1869.1	550.3	2238.6	402.7	1539.4	300.5	1201.8	263.5	821.4	175.0	2.0	3.2	1.8	0.0	0.0	0.0
904	2431.7	466.7	1793.8	585.9	2533.7	248.5	1499.5	238.8	1130.2	234.1	800.8	142.5	2.5	3.6	3.1	0.0	0.0	0.0
905	2473.5	321.2	1683.2	410.7	2479.1	314.7	1559.5	376.3	1129.0	216.6	830.2	143.9	1.9	2.7	2.5	2.5	0.0	0.0
906	2723.0	611.2	1880.4	593.3	2444.6	289.4	1540.6	511.5	1111.5	147.6	793.0	99.8	1.4	3.0	2.1	0.0	0.0	0.0

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
907	2501.6	624.6	1870.7	677.2	2689.5	311.5	1559.0	500.8	1128.0	191.4	835.1	87.0	3.0	3.3	2.6	0.0	0.0	5.8
908	2378.2	575.4	1710.4	683.3	2835.0	331.6	1579.2	534.3	1093.3	200.7	854.2	102.5	2.8	4.5	2.3	0.0	0.0	1.0
909	2285.1	563.4	1698.6	709.0	2942.2	385.6	1636.2	585.4	1094.6	137.0	811.7	140.7	3.2	3.6	2.4	0.0	0.0	0.0
910	2374.9	686.1	1721.4	761.4	3000.2	416.7	1660.2	609.9	1162.2	187.4	855.8	219.4	0.0	2.2	1.3	7.6	0.0	1.5
911	2225.9	857.1	1646.1	868.5	2945.6	321.2	1603.0	479.1	1192.6	249.9	863.9	249.4	0.8	1.3	0.7	15.2	0.0	8.9
912	1703.5	779.7	1536.4	521.9	2912.6	294.1	1530.6	381.1	1240.2	342.4	954.2	213.4	0.5	1.5	1.3	7.6	0.0	2.0
913	1573.9	758.0	1517.9	577.6	2918.3	410.0	1607.6	412.2	994.8	403.6	899.7	230.5	0.8	1.6	1.3	0.0	0.0	13.2
914	1525.9	764.5	1491.6	695.6	2935.6	480.3	1692.1	467.2	866.9	417.2	909.3	305.5	1.0	1.1	1.8	0.0	0.0	0.0
915	1404.8	691.2	1372.4	646.3	2775.3	525.7	1712.5	526.4	863.2	437.6	918.2	413.8	0.8	0.9	1.7	0.0	0.0	0.0
916	1379.1	593.0	1267.3	575.9	2483.5	518.9	1695.4	488.6	831.7	433.2	898.1	496.3	1.1	1.4	2.2	0.0	0.0	0.0
917	1387.6	615.9	1273.4	669.4	2523.7	587.4	1800.9	633.4	792.6	402.8	843.0	569.7	1.1	1.4	2.3	0.0	0.0	0.0
918	1438.6	580.3	1502.0	709.7	2580.9	505.7	1721.9	548.0	716.3	407.3	841.5	577.5	0.5	1.7	1.6	3.1	0.0	0.0
919	1548.1	629.1	1370.4	756.5	2572.3	447.5	1657.8	534.3	714.3	405.9	853.4	570.5	0.9	1.5	3.1	2.5	0.0	2.3
920	1571.2	716.3	1426.0	740.3	2612.8	433.1	1545.8	611.4	637.6	393.4	826.5	583.4	1.1	1.6	1.4	0.0	0.0	0.0
921	1322.6	605.0	1349.5	709.7	2588.9	393.8	1555.0	502.0	571.8	357.1	789.9	480.3	1.0	1.8	0.9	0.0	0.0	1.5
922	1149.8	373.2	1152.8	536.6	2523.8	466.5	1529.1	459.7	583.6	394.5	825.7	530.4	1.5	1.9	1.4	0.0	0.0	0.0
923	1168.7	324.4	1063.5	381.1	2590.4	655.5	1775.2	685.1	592.8	406.8	835.8	536.4	1.3	1.5	1.0	0.0	0.0	0.0
924	1150.1	340.1	1061.3	309.7	2576.0	572.5	1728.2	677.9	586.0	362.8	774.9	516.3	1.2	1.5	1.1	0.0	0.0	0.0
925	1525.2	297.3	1114.4	296.0	2238.2	452.3	1638.7	508.2	601.4	325.9	745.9	452.6	1.2	0.9	0.9	0.0	1.8	0.0
926	1750.5	324.6	1209.8	302.9	2155.8	557.5	1735.4	657.2	590.5	295.4	706.0	444.0	1.2	0.9	1.2	0.0	0.5	0.0
927	1870.2	341.1	1248.8	387.1	2043.1	536.3	1746.6	683.8	540.5	249.0	646.6	342.3	1.7	1.2	1.6	0.0	0.0	0.0
928	1976.3	405.2	1326.8	452.6	2083.4	566.4	1761.8	794.8	520.6	203.3	632.6	301.0	1.1	1.6	2.0	0.0	0.0	0.0
929	1518.5	480.1	1434.4	491.2	2137.1	673.5	1795.6	882.4	515.3	206.9	610.7	269.5	0.3	1.5	1.2	0.0	0.0	0.0
930	1566.0	443.8	1364.5	364.5	2154.6	713.2	1799.4	901.0	615.0	207.2	644.5	275.8	1.1	0.8	1.6	0.0	0.0	0.0
1001	1562.6	433.4	1399.6	353.0	2167.9	915.7	1938.6	1048.3	646.7	231.9	695.3	327.1	0.6	1.7	1.1	0.0	0.0	0.0
1002	1492.6	491.7	1451.5	423.4	1978.2	902.0	1922.5	913.8	645.5	227.7	706.8	332.7	0.8	0.6	1.0	0.0	0.0	0.0
1003	1513.5	521.5	1555.1	486.4	1871.2	777.7	1810.7	833.1	630.4	152.2	663.1	237.4	1.3	0.8	1.6	0.0	0.0	0.0
1004	1669.7	627.7	1699.8	665.9	1797.5	702.5	1747.3	794.6	815.9	237.3	710.1	252.0	0.7	1.2	0.9	0.0	0.0	0.0
1005	1448.8	578.9	1660.5	702.0	1733.4	645.1	1707.7	792.4	637.5	181.2	671.4	229.2	0.7	0.9	0.6	0.0	0.0	0.0
1006	1100.0	294.6	1353.6	431.1	1693.5	601.6	1660.2	697.8	833.5	158.3	708.1	187.4	0.5	0.5	0.5	0.0	0.0	0.0
1007	1071.1	224.9	1289.1	332.3	1654.3	601.1	1626.4	689.1	847.5	296.5	784.7	271.2	0.7	0.5	0.6	0.0	0.0	0.0
1008	1137.4	260.5	1315.5	335.4	1624.2	561.0	1537.3	692.6	872.4	330.4	736.0	215.9	0.4	0.3	0.9	0.0	0.0	0.0
1009	1105.3	255.2	1346.8	355.5	1561.4	658.7	1702.8	782.9	852.8	294.1	729.2	219.1	0.5	0.5	0.4	0.0	0.0	0.0
1010	1312.5	276.8	1385.3	436.3	1474.0	628.3	1694.0	803.2	918.2	285.2	775.2	239.9	0.5	0.5	0.5	0.0	0.0	0.0
1011	1473.5	545.3	1572.9	649.3	1436.6	609.0	1611.0	656.7	863.9	276.7	764.6	314.0	0.5	0.5	0.9	0.0	0.0	0.0
1012	1518.8	578.6	1548.2	689.4	1625.0	585.6	1581.9	446.5	502.0	293.2	799.9	331.9	–	0.5	0.5	0.0	0.0	4.1
1013	1502.9	578.7	1583.2	701.2	1382.3	438.4	1433.9	323.4	778.9	363.3	882.7	445.0	–	0.3	0.2	0.0	0.0	0.0
1014	1405.8	456.2	1471.8	707.5	1279.6	413.5	1391.3	300.2	463.4	306.6	792.9	423.9	–	0.2	0.3	0.0	9.9	0.0
1015	1397.0	497.1	1491.4	984.4	1262.2	452.8	1382.6	343.0	336.2	312.8	709.5	435.9	–	0.1	0.3	0.0	0.0	13.0
1016	1332.4	515.0	1485.1	1020.7	1472.6	563.7	1262.2	382.6	289.4	233.4	633.9	398.3	–	0.2	0.2	0.0	0.0	11.7
1017	1288.4	537.3	1508.8	895.2	1263.4	667.2	1279.8	380.9	143.5	235.8	635.4	364.2	–	0.3	0.4	0.0	0.0	2.0
1018	1066.2	424.4	1357.3	551.7	1234.3	614.8	1220.6	390.5	50.7	96.8	452.2	277.4	–	0.2	0.4	0.0	2.8	0.0
1019	1104.3	431.2	1350.9	380.2	1227.2	615.5	1224.2	370.2	130.4	30.2	408.3	229.5	–	0.0	0.3	0.0	3.6	0.0
1020	1251.8	510.8	1444.4	411.0	1226.7	674.7	1241.4	352.3	260.9	92.8	483.5	259.6	–	0.1	0.3	0.0	2.3	0.0
1021	1535.4	560.1	1454.5	400.8	1137.9	746.0	1138.1	395.6	271.9	170.7	541.9	370.7	–	0.1	0.4	0.0	0.0	0.0
1022	1543.1	640.5	1505.6	444.6	1134.4	786.3	1167.2	436.0	272.8	215.6	554.9	340.8	–	0.2	0.3	0.0	0.0	0.0
1023	1565.3	708.7	1583.6	519.9	1117.8	814.2	1167.5	401.7	294.8	222.6	560.7	345.0	–	0.2	0.3	0.0	0.0	0.0
1024	1284.2	604.4	1482.9	512.5	1077.2	826.9	1132.4	350.3	319.6	234.4	568.1	360.7	–	0.2	0.4	0.0	0.0	0.3
1025	1389.1	618.5	1403.0	514.5	1110.7	831.1	1122.9	339.6	336.1	251.0	557.6	368.1	–	0.2	0.3	0.0	0.0	0.0
1026	1462.0	631.3	1369.4	529.4	1113.0	802.7	1132.1	332.5	339.0	254.3	555.2	360.8	–	0.3	0.2	0.0	0.0	0.0
1027	1356.0	658.9	1385.1	543.8	342.0	786.3	1143.1	358.2	338.7	260.1	565.3	391.3	–	0.3	0.2	0.0	0.0	3.6
1028	1297.1	613.5	1341.6	478.3	351.3	794.1	1149.6	361.7	330.9	256.1	558.0	368.9	–	0.1	0.3	0.0	7.8	0.0
1029	1353.5	364.2	1313.5	467.2	356.7	805.5	1157.0	369.2	336.4	255.8	557.2	344.0	–	0.1	0.2	0.0	0.0	0.0

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
1030	1139.4	501.0	1469.9	547.3	353.3	453.3	962.2	19.6	343.6	257.7	557.4	323.0	-	0.1	0.3	0.0	0.0	0.0
1031	369.2	332.3	332.3	457.2	322.9	-	508.9	20.8	252.1	257.9	418.3	326.0	-	0.0	0.3	0.0	0.0	0.0
1101	446.0	324.2	324.2	114.2	-	-	-	-	13.0	246.0	152.7	328.7	-	-	-	0.0	0.0	0.0
1102	515.0	329.6	329.6	113.0	-	-	-	-	21.2	231.6	137.9	328.0	-	-	-	0.0	0.0	0.0
1103	562.7	323.2	323.2	107.4	-	-	-	-	20.1	186.4	105.7	252.0	-	-	-	0.0	3.3	0.0
1104	382.4	244.5	244.5	106.9	-	-	-	-	-	98.2	10.2	150.4	-	-	-	0.0	9.1	0.0
1105	296.0	211.7	211.7	121.4	-	-	-	-	-	-	-	119.3	-	-	-	0.0	0.0	0.0
1106	296.5	206.2	206.2	-	-	-	-	-	-	-	-	111.0	-	-	-	0.0	0.0	0.0
1107	-	-	-	-	-	-	-	-	-	-	-	124.5	-	-	-	0.0	0.0	0.3
1108	-	-	-	-	-	-	-	-	-	-	-	130.0	-	-	-	0.0	0.0	0.0
1109	-	-	-	-	-	-	-	-	-	-	-	135.8	-	-	-	2.5	0.0	0.0
1110	-	-	-	-	-	-	-	-	-	-	-	162.3	-	-	-	5.1	0.0	0.0
1111	-	-	-	-	-	-	-	-	-	-	-	144.8	-	-	-	5.1	0.0	6.3
1112	-	-	-	-	-	-	-	-	-	-	-	134.2	-	-	-	0.0	0.0	2.8
1113	-	-	-	-	-	-	-	-	-	-	-	116.8	-	-	-	0.0	0.0	0.0
1114	-	-	-	-	-	-	-	-	-	-	-	102.9	-	-	-	0.0	0.0	0.0
1115	-	-	-	-	-	-	-	-	-	-	-	96.1	-	-	-	2.5	0.0	0.0
1116	-	-	-	-	-	-	-	-	-	-	-	97.1	-	-	-	0.0	0.0	0.0
1117	-	-	-	-	-	-	-	-	-	-	-	94.6	-	-	-	0.0	0.0	0.0
1118	-	-	-	-	-	-	-	-	-	-	-	95.5	-	-	-	0.0	0.0	0.0
1119	-	-	-	-	-	-	-	-	-	-	-	102.0	-	-	-	0.0	1.3	0.0
1120	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	0.0	0.0
1121	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	0.0	0.0
1122	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.1	0.0	1.8
1123	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	0.3	0.0
1124	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	0.5	0.0
1125	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	1.0	0.0
1126	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	1.5	0.0
1127	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	0.0	0.0
1128	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.5	0.0	0.0
1129	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.5	0.0	0.0
1130	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.1	0.0	0.0

APPENDIX B

PROCEDURES AND COMPUTER PROGRAM FOR SMOOTHING DATA

The following is a computer program for smoothing one time series, $\{X_t\}$, into another, $\{Y_t\}$, by the linear operation

$$Y_t = \sum_{r=-q}^{+s} a_r \cdot X_{t+r}$$

where $\{a_r\}$ are a set of weights. In order to smooth out local fluctuations and estimate the local mean, the weights should be clearly chosen so that $a_r = 1$, and then the operation is often referred to as a moving average. Moving averages are often symmetric with $s=q$ and $a_j=a_{-j}$. The simplest example of a symmetric smoothing filter is the simple moving average for which $a_r=1/(2q+1)$ for $r=-q,\ldots,+q$, and $S_m(X_t)$ = smoothed value of X_t

$$= \frac{1}{2q+1} \sum_{i=t-q}^{t+q} X_i$$

```
100 REM %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
110 REM THIS PROGRAM FOR SMOOTHING THE CURVE OF THE SERIES.
120 REM INPUT SMOOTHING INTERVAL (ODD NUMBER)
130 REM INPUT SMOOTHING COEFFICIENTS(EX.1,2,3,2,1 OR 1,2,3,4,3,
              2,1). SERIES DATA SUPLIED BY RIGHT SIDE DISK .
              OUTPUT FILE NAME
140 REM OUTPUT SERIES DATA WHICH SMOOTHED
150 REM PROGRAMMER SUNG KIM MAR. 16,1981
160 REM %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
170 DIM X(244),C1(10),Y(244)
180 READ X$,Y$ : REM ............READ INPUT AND OUT FILE
190 DATA LOAD DC OPEN R X$
200 DATA LOAD DC X()
210 READ N1    : REM .............READ SMOOTH INTERVAL
220 C=0
225 REM ................... READ SMOOTH COEFFICIENTS
230 FOR I=1 TO N1 : READ C1(I) :C=C+C1(I): NEXT I
240 N9=(N1-1)/2 : REM .....COMPUTE STARTING DATE
250 N2=N9+1
260 N3=244-N2+1
270 FOR I=N2 TO N3 : REM ...COMPUTE SMOOTHED SERIES
280 T=0
290 FOR J=1 TO N1 : K1=I-N9+J-1 : T=T+X(K1)*C1(J) : NEXT J
300 Y(I)=T/C
310 NEXT I
320 FOR L=N2 TO N3 : X(L)=Y(L) : NEXT L
330 DATA SAVE DC OPEN R 10 ,Y$ : REM .....SAVE OUTPUT
340 DATA SAVE DC X()
350 DATA SAVE DC CLOSE
360 END
370 DATA "ET78","ET78SM1",3,1,1,1
```

APPENDIX C

COMPUTER PROGRAM TO COMPUTE AUTOCORRELATION COEFFICIENTS

```
100 REM %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
110 REM THIS PROGRAM COMPUTE AUTO CORRELATION AS A
   TECHNIQUE FOR INVESTIGATING RELATION WITHIN A HYDROLOGIC
   PROCESSES.    PRGRAMER; SUNG  KIM (3/23/81)
120 REM INPUT STARTING NO.,M1  ENDING NO.,M2
              NUMBER OF LAG TIME(GUESS),K
              VALUE OF EACH TIME SERIES,X(I)-SUPLIED BY
130 REM       THE RIGHT SIDE DISK.
140 REM OUTPUT  AUTO CORRELATION FACTOR & CONFIDENCE INTERVAL
               FOR LAG TIME( FROM 0 TO K ).
150 REM %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
160 DIM X(244),R(16),P1(16),P2(16)
170 READ N : FOR K9=1 TO N
180 READ X$ : REM .............READ INPUT FILE NAME
190 READ Y$ : REM .............READ OUTPUT FILE NAME
200 DATA LOAD DC OPEN R  X$
210 DATA LOAD DC X()
220 READ M1 : REM ...............READ STARTING DATE
230 READ M2 : REM ...............READ ENDING DATE
240 FOR I=M1 TO M2
250 I1=I-M1+1
260  X(I1)=X(I)
270 NEXT I
280 REM
290 N=M2-M1+1
300 K1=15
310 FOR K=0 TO K1
320 K2=K+1
330 S1,S2,S3,S4,S5=0.0
340 N1=N-K
350 FOR I= 1 TO N
360 J=I+K
370 S1=S1+X(I)
380 S2=S2+X(J)
390 S3=S3+X(I)^2
400 S4=S4+X(J)^2
410 S5=S5+X(I)*X(J)
420 NEXT I
430 U1=S5/N1 : U2=S1*S2/N1^2 : U3=(S3/N1-S1^2/N1^2)^.5
   : U4=(S4/N1-(S2/N1)^2)^.5
440 R(K2)=(U1-U2)/(U3*U4) : REM .....COMPUTE COEFFICIENTS
450 P=1.645*(N-K)^.5  : REM .........COMPUTE CONFIDENCE INTERVAL

460 P1(K2)=(-1+P)/(N-K) : REM ......UPPER C.L.
470 P2(K2)=(-1-P)/(N-K) : REM ......LOWER C.L.
```

```
480 NEXT K
490 PRINT HEX(0C)
500 PRINT
510 PRINT
520 PRINT "AUTO CORRELATION"
530 PRINT "NAME OF FLOW=";X$,"OUTPUT FILENAME=";Y$
540 PRINT "STARTING DATE=";M1,"ENDING DATE=";M2
550 PRINT
560 PRINT
570 PRINTUSING 660
580 PRINTUSING 670
590 FOR K1=0 TO K :K2=K1+1 : PRINTUSING 680,K1,R(K2),P1(K2),P2(K
2)
600 NEXT K1
610 REM
620 DATA SAVE DC OPEN F 8,Y$
630 DATA SAVE DC R() : DATA SAVE DC P1() : DATA SAVE DC P2()
640 DATA SAVE DC CLOSE
650 NEXT K9
660%   LAG(K)          CORR.(R)      CONF.INTVL
670%                                   UPPER         LOW
680%     ###           +#.####       +#.####      +#.####
690 END
700 DATA 1
710 DATA "SNIN79","ACRSI91",62,168
```

APPENDIX D

COMPUTER PROGRAM TO COMPUTE LAG CROSS CORRELATION COEFFICIENTS

```
100 REM %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
110 REM THIS PROGRAM COMPUTE LAG CROSS CORRELATION AS A
        TECHNIQUE FOR INVESTIGATING RELATION BETWEEN TWO HYDRO
        -LOGIC SERIES.          PROGRAMER; SUNG  KIM (3/12/81)
120 REM INPUT STARTING NO.,M1  ENDING NO.,M2
              NUMBER OF LAG TIME(GUESS),K
              VALUE OF EACH TIME SERIES,X(I),Y(I)-SUPLIED BY
130 REM       THE RIGHT SIDE DISK.
140 REM OUTPUT  CROSS CORRELATION FACTOR & CONFIDENCE INTERVAL
                FOR LAG TIME( FROM 1 TO K ).
150 REM %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
160 DIM X(244),Y(244),R(50),P1(50),P2(50),Z(244)
180 READ X$ : REM ..............READ FIRST FILE
190 READ Y$ : REM ..............READ SECOND FILE
210 DATA LOAD DC OPEN R  X$
220 DATA LOAD DC X()
230 DATA LOAD DC OPEN R  Y$
240 DATA LOAD DC Y()
245 READ K1 : REM ..............READ LAG INTERVAL FOR COMPUTING
250 READ M1,M2 : REM ..........READ STARTING AND ENDING DATE
260 FOR I=M1 TO M2 : T1=I-M1+1 : X(T1)=X(I) : Y(T1)=Y(I) : NEXT
I : REM ......................DIFFERCING
380 REM
390 N=M2-M1+1
410 FOR K=0 TO K1
420 K2=K+1
430 S1,S2,S3,S4,S5=0.0
440 FOR I= 1 TO N
450 S1=S1+X(I)
460 S2=S2+Y(I)
470 S3=S3+X(I)^2
480 S4=S4+Y(I)^2
490 NEXT I
500 N1=N-K
510 FOR I=1 TO N1
520 T1=I+K
530 S5=S5+X(I)*Y(T1)
540 NEXT I
550 U1=S1/N : U2=S2/N : U3=S3/N : U4=S4/N
560 R(K2)=(S5/N1-S1*S2/N^2)/((U3-U1^2)*(U4-U2^2))^.5 : REM .....
...............................COMPUTE COEFFICIENTS
570 P=1.645*(N-K)^.5 : REM .......COMPUTE CONFIDENCE INTERVAL
580 P1(K2)=(-1+P)/(N-K)
590 P2(K2)=(-1-P)/(N-K)
600 NEXT K
```

```
620 PRINT
630 PRINT
640 PRINT "LAG CORRELATION"
650 PRINT "INFLOW=";X$,"OUTFLOW=";Y$
660 PRINT "STARTING DATE=";M1,"ENDING DATE=";M2
670 PRINT
680 PRINT
690 PRINTUSING 730
700 PRINTUSING 740
710 FOR K1=0 TO K :K2=K1+1 : PRINTUSING 750,K1,R(K2),P1(K2),P2(K
2): NEXT K1
715 PRINT HEX(0C)
720 GOTO 250
730%   LAG(K)          CORR.(R)        CONF.INTVL
740%                                    UPPER           LOW
750%     ###            +#.####         +#.####     +#.####
760 END
770 DATA "ET79SA5","SNIM079", 15,31,122,62,153,92,183,123,214
```

APPENDIX E

COMPUTER PROGRAM TO PREDICT IRRIGATION DIVERSIONS ON A DAILY BASIS

```
100 REM ******************************************************
        THIS IS THE PROGRAM TO COMPUTE THE DIVERSION WATER
        REQUIREMENT ON DAILY BASIS.
110 REM INPUT DATA ARE GIVERN AT THE END OF THIS PROGRAM WITH
        DATA COMMEND.
        ..................INPUT DATA..........................
120 REM        1.NAME OF DISTRICT(LIMIT 20 CHARACTERS)
               2.IRRIGATED AREA OF THE DISTRICT, A1, IN ACRES
               3.AVERAGE IRRIGATION PERIOD, I9, IN DAYS
130 REM        4.AVERAGE APPLICATION EFFICIENCY, F1, IN PERCENTS
               5.ADVANCE LEAD TIME, A9, IN DAYS
               6.CONVEYANCE TIME, C9, IN DAYS
140 REM        7.DAILY WATER USE COEFFICIENTS (FROM SUNDAY TO
                 SATURDAY), W(I), NO DIMENSION
150 REM        8.SEEPAGE COEFFICIENTS,
150 REM        8.SEEPAGE COEFFICIENTS,
                 YESTERDAY'S DIVERSION,
                 YESTERDAY'S CONVEYANCE LOSS
160 REM        9.MINIMUM OUTFLOW
170 REM       10.DATE, D0, AND DAY, D1
                 EX. MAY, 1 >>> 501 ,  SUNDAY >>> 1 ,---,
                    SATURDAY >>> 7
180 REM       11.EVAPOTRANSPIRATION, E0, IN MM
              12.PRECIPITATION, P1, IN MM
190 REM

200 REM ......................................................
210 REM ....................OUTPUT.............................
               1.NAME OF THE DISTRICT AND TOTAL AREA
               2.DATE
220 REM        3.RAINFALL
               4.ACCUMULATED AVERAGE ET FOR DIVERSION
               5.DEEP PERCOLATION
230 REM        6.SEEPAGE
               7.DIVERSION WATER REQUIREMENT
240 REM ......................................................
250 REM   PROGRAMED BY SUNG KIM (6/20/81)
          REFERENCE M.S. THESIS,"DAILY WATER DEMAND PREDICTION
          MODEL FOR IRRIGATION DISTRICT", AGR. ENGR., UNIV. OF
260 REM   IDAHO, 1981
270 REM ******************************************************
280 REM
290 DIM W(7),E0(244),R0(244),N$40,W1(244),E1(244),E2(244),L(244)
,D(244)
300 REM ***********READ INFORMATION ABOUT DISTRICT*************
```

```
310 REM READ NAME OF DISTRICT,TOTAL AREA:READ N$,A1
320 REM READ AVERAGE IRRIGATION PERIOD, ADVANCE LEAD TIME,
 CONVEYANCE TIME:READ I9,A9,C9
330 REM READ LOSS COEFFICIENTS:READ C0,C1,C2
340 REM READ FIRST ASSUMING DIVERSION ,AND MINIMUM OUTFLOW:READ
D0,M9
350 REM READ DAILY WATER USE COEFFICIENTS:FOR I=1 TO 7:READ W(I)
:NEXT I
354 READ D9
355 READ E$,R$
360 PRINT "DISTRICT=";N$:PRINT "TOTAL AREA=";A1;"ACRES"
370 PRINT :PRINTUSING 640:PRINTUSING 650:PRINTUSING 660
380 REM ***********READ DAILY DATA**************************
381 DATA LOAD DC OPEN F X$ : DATA LOAD DC E0()
382 DATA LOAD DC OPEN F Y$ : DATA LOAD DC R0()
383 FOR I=1 TO 244
384 W1(I)=D9:D9=D9+1
385 IF D9<8 THEN 387
386 D9=D9-7
387 NEXT I
390 FOR I=I9 TO 244 :E=0
391 FOR J=1 TO I9 : K=I-J+1
392 W9=W1(K) : E=E+(E0(K)*W(W9)+R0(K))*A1/45754
393 NEXT J
394 E1(I)=E/I9
395 NEXT I
400 FOR I=(I9+A9) TO 240 : E=0
401 FOR J=(I-A9) TO (I-A9+C9+1)
402 E=E+E1(J):NEXT J
403 E2(I)=E/C9
404 NEXT I
500 FOR I=46 TO 168
501 L(I)=C0+C1*I+C2*D0
502 D(I)=E2(I)+L(I)+M9
503 IF ABS(D(I)-D0)<10 THEN 505
504 D0=(D0+D(I))/2 :GOTO 501
505 NEXT I
600 FOR I=46 TO 168
610 PRINT I,W1(I),E2(I),D(I)
620 NEXT I
630 REM ****************************************************
640% DATE  RAINFALL   ET    DP    SEEPAGE    DIVERSION
650%        -----DEPTH----------       VOLUME  DEPTH   VOLUME
660%            (INCHES/DAY)      (AC-FT/DAY) (IN) (AC-FT/DAY)
670% ####     #.##     #.##  #.##   ####.#   #.##  #####.##
680 END
690 REM ****************DISTRICT INFORM.*****************
700 DATA "IDAHO IRRIGATION DISTRICT", 28577
710 DATA 6,1,4
720 DATA 101.51,-5.6187,.88774
730 DATA 2000,400
740 DATA .7,1.2,1.1,1.0,1.0,1.2,.8
750 DATA 4
760 DATA "ET78A","PRCP78"
```

SELECTED WATER RESOURCES ABSTRACT Input Transaction Form	1. *Report No.*	2.	3. *Accession No.*
4. *Title* Analyzing and Predicting Irrigation Diversions in Southeastern Idaho			5. *Report Date* 6. September 1981 8. *Performing Organization Report No.*
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15. *Supplementary Notes* Partial Completion Reports, User's Guide to UIMIP and MTRX, Methodology for Optimization of an Irrigation with Storage Reservoirs, and Soil Water Intake Rates and Surface Irrigation System Characteristics by Soil Series in Southeastern Idaho.

16. *Abstract* A study was done to analyze the daily water flow data from two large irrigation districts located in the Upper Snake River region of southeastern Idaho and to develop a methodology for predicting daily water diversions. Data collected during the 1978, 1979, and 1980 irrigation seasons were used for this study.

Crop consumptive water use was estimated by the combination method on a daily basis. Crop consumptive use estimates varied greatly on a daily basis, and the patterns were quite different from year to year.

Seasonal irrigation water use amounts were different for different years for the different districts, but the seasonal water use patterns were similar for different years and districts.

Graphical and statistical methods were used to determine fluctuations and relations among inflow, outflow, evapotranspiration, and precipitation. A slight change of evapotranspiration resulted in a rather large change of inflow. A weekly cycle was found to exist within outflows, but no significant frequency was found within inflows.

Relationships between time and diversion requirements were established. Based on the time effects, proper consumptive irrigation requirements were estimated at the district level.

A computer program was developed for predicting water diversions for the study area and did a reasonable job.

17a. *Descriptors* Mechanics of groundwater movement; effects of control programs and devices on the stage and time distribution of streams; water quantity and quality requirements of various uses, both diversion and consumption.

17c. *COWRR Field & Group*
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