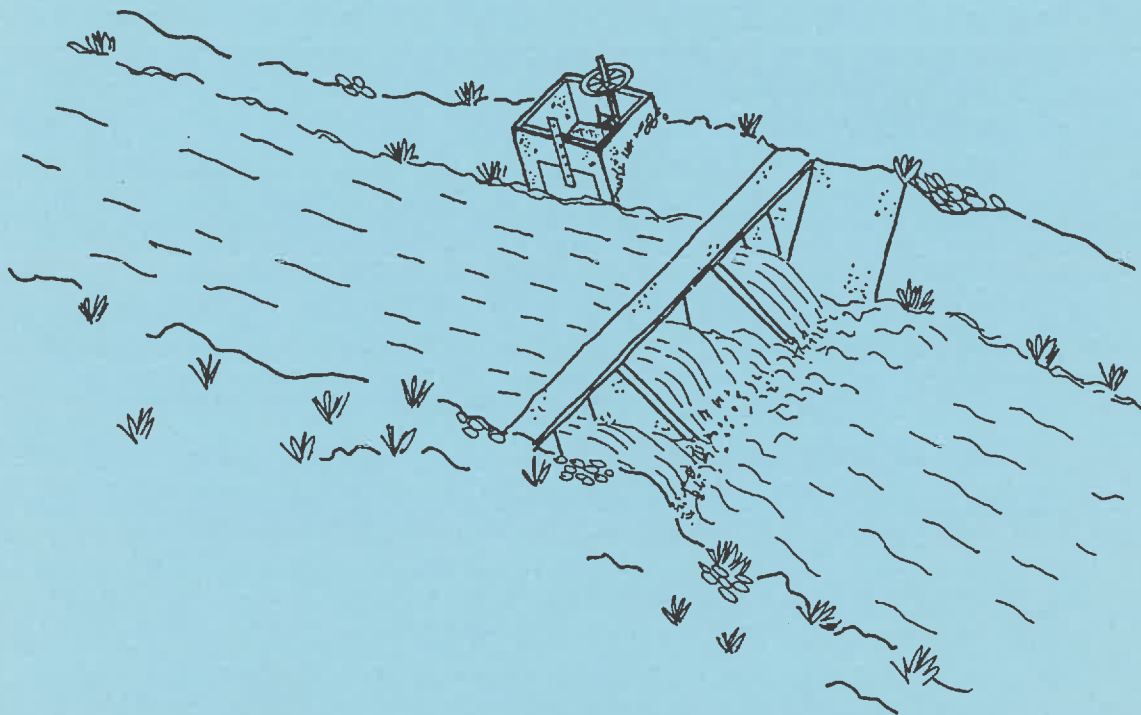


ALTA IRRIGATION DISTRICT SURFACE WATER STUDY



Kings River Conservation District



December 1991

ALTA IRRIGATION DISTRICT
SURFACE WATER STUDY

Prepared by the

KINGS RIVER CONSERVATION DISTRICT



December 1991

EXECUTIVE SUMMARY

A study was conducted of the surface water delivery system of Alta Irrigation District (Alta) located on the east side of California's San Joaquin Valley. The study goal was to quantify the losses of the delivery system for use in district planning and to gain information that will be needed for a future groundwater study.

The following losses of Alta's surface water delivery system were estimated:

- Seepage
- Evaporation
- Evapotranspiration (ET) of Bank Vegetation
- Operational Spillage

In addition, a water balance was conducted for wet (1984) and dry (1990) years to estimate the amount of unaccounted water.

Seepage estimates were based on infiltration rates that were developed using blocked canal section tests and U.S.D.A. Soil Conservation Service (SCS) permeability values. SCS soil maps were used to characterize the soil types of individual canal segments.

Evaporation and ET of bank vegetation estimates were based on local crop reference ET. Evaporation estimates were most sensitive to canal section width and length. Bank ET estimates were most sensitive to canal section length and assumptions regarding the amount of weed growth along channels.

Operational spillage estimates were based on interviews with canal operators employed by Alta. The operators estimated from recollection typical flows at system spill points for wet and dry years.

Seepage was determined to be the most significant loss of Alta's distribution system. Seepage was estimated to be approximately 23 percent of the district's total diversion. Wet year operational spillage loss was estimated at about 5 percent of total diversion. Estimates of losses due to evaporation, bank ET, and dry year spillage were insignificant (Table 1).

A system water balance was conducted to inventory the amount of water that enters Alta's delivery system as diversions and exits the system as losses and deliveries. The water balance showed that a significant volume of water is unaccounted for in the dry year of 1990 (Table 2). Analysis of recorded deliveries from additional years showed an apparent correlation between water year and the amount of unaccounted water. The unaccounted water appears to be insignificant during average and above average water years and significant (up to 30 percent of diversion) during dry years (Figure 1).

The reason for variation in unaccounted water is unknown. Some possible explanations could be based on the inexactness of Alta's delivery measurement and the potential for measured water deliveries to be returned to canals as farm runoff.

Table 1 Summary of Alta I.D. Distribution System Losses				
Loss	Wet Year (1984)		Dry Year (1990)	
	Percent of Diversion	Percent of Total Losses	Percent of Diversion	Percent of Total Losses
Seepage	23.1%	77.5%	23.6%	94.8%
Evaporation	0.8%	2.7%	0.7%	2.8%
Bank ET	0.4%	1.3%	0.1%	0.4%
Spill	5.5%	18.5%	0.5%	2.0%
Total	29.8%	100.0%	24.9%	100.0%

Table 2						
Alta I.D. Water Balance						
Type of Water Source, Use, or Loss	1984 (Wet)			1990 (Dry)		
	Amount of Source, Use, or Loss (AF)		Percent of Diversion	Amount of Source, Use, or Loss (AF)		Percent of Diversion
Diversion		212,941	100.0%		58,284	100.0%
Losses						
Seepage	49,306		23.1%	13,727		23.6%
Evaporation	1,715		0.8%	430		0.7%
Bank ET	770		0.4%	80		0.1%
Spill	11,656		5.5%	262		0.5%
Sub-Total		63,447	29.8%		14,499	24.9%
Delivered		148,827	69.9%		28,137	48.3%
Unaccounted		643	0.3%		15,658	26.9%

Figure 1

Alta I.D. Unaccounted Water from 1976 to 1990

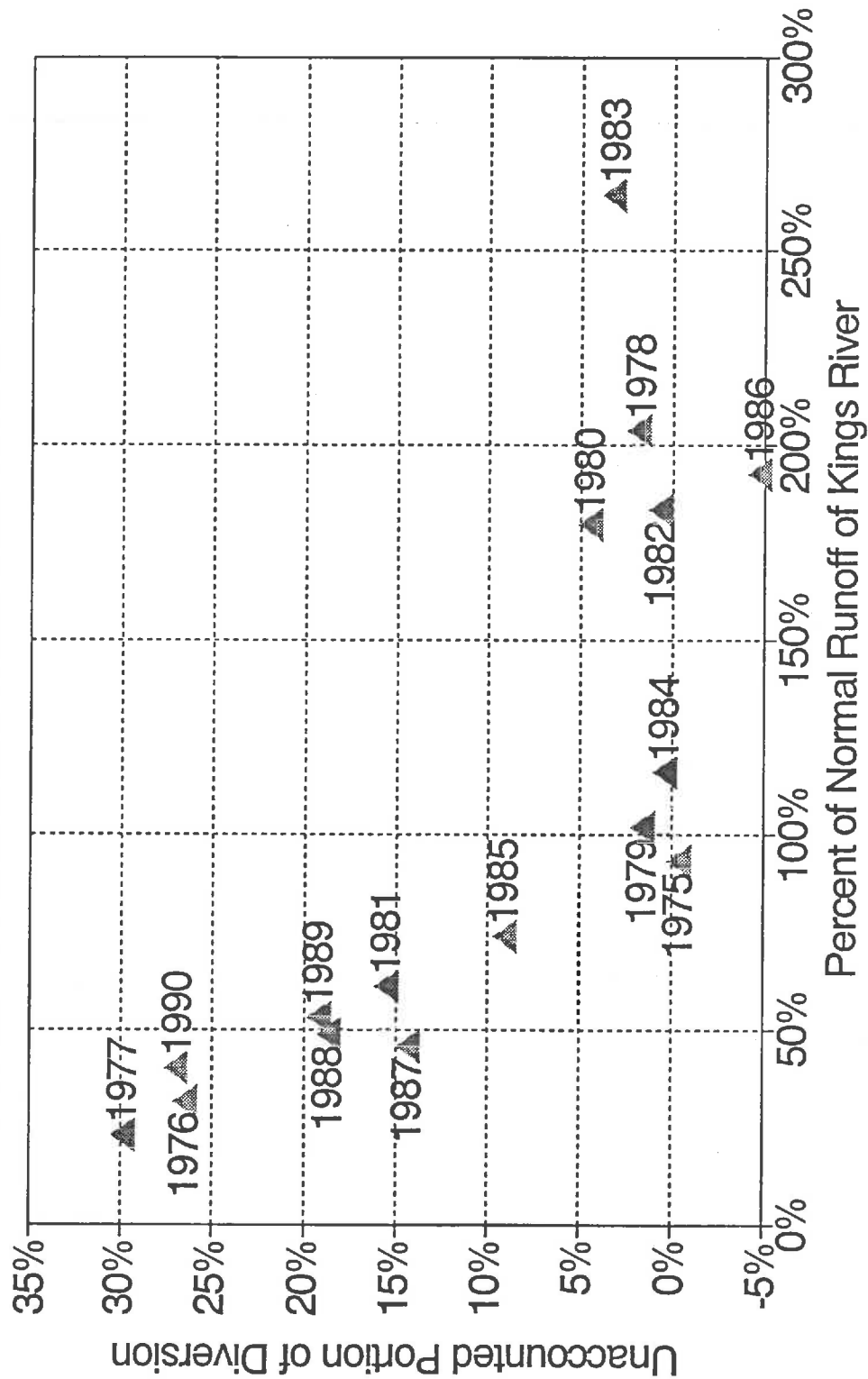


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I

INTRODUCTION

1. ALTA IRRIGATION DISTRICT

The Alta Irrigation District (Alta) is located on the east side of the San Joaquin Valley southeast of the City of Fresno. The district encompasses a land area of approximately 130,000 acres in parts of Fresno, Tulare, and Kings Counties. The district is bounded roughly by the Kings River on the west and the Sierra Nevada Foothills on the east (Figure I-1).

The district is composed primarily of alluvial fans sloping to the southwest with elevations ranging from about 425 feet at the northern point to 270 feet in the southwest corner.

Kings River water was first diverted to the Alta area in the early-1880's by private land companies. The Alta Irrigation District was created in 1888 by local landowners to help ensure a reliable and equitable source of irrigation water.

Alta's annual entitlement of Kings River water has ranged from 38,700 to 253,300 acre-feet (Alta, 1990), with an average annual diversion of 195,035 acre-feet (KRW, 1991). Alta typically diverts a relatively steady flow rate of about 700 cubic-feet per second (cfs) starting in May for a period of 28 to 195 days (Alta, 1990). The volume and duration of Alta's diversion is a function of their water rights and the yearly runoff from the Kings River. Kings River runoff can fluctuate greatly from year to year, and the watershed is prone to periods of drought.

2. HISTORY OF SURFACE WATER STUDY

The Alta area receives precipitation of less than 12 inches per year yielding a useable volume of water of less than 100,000 acre-feet on average. Combined with an average annual surface entitlement of 195,035 acre-feet and crop demand of about 325,000 acre-feet, Alta farmers must rely on a secondary source of irrigation water, even in average water years.

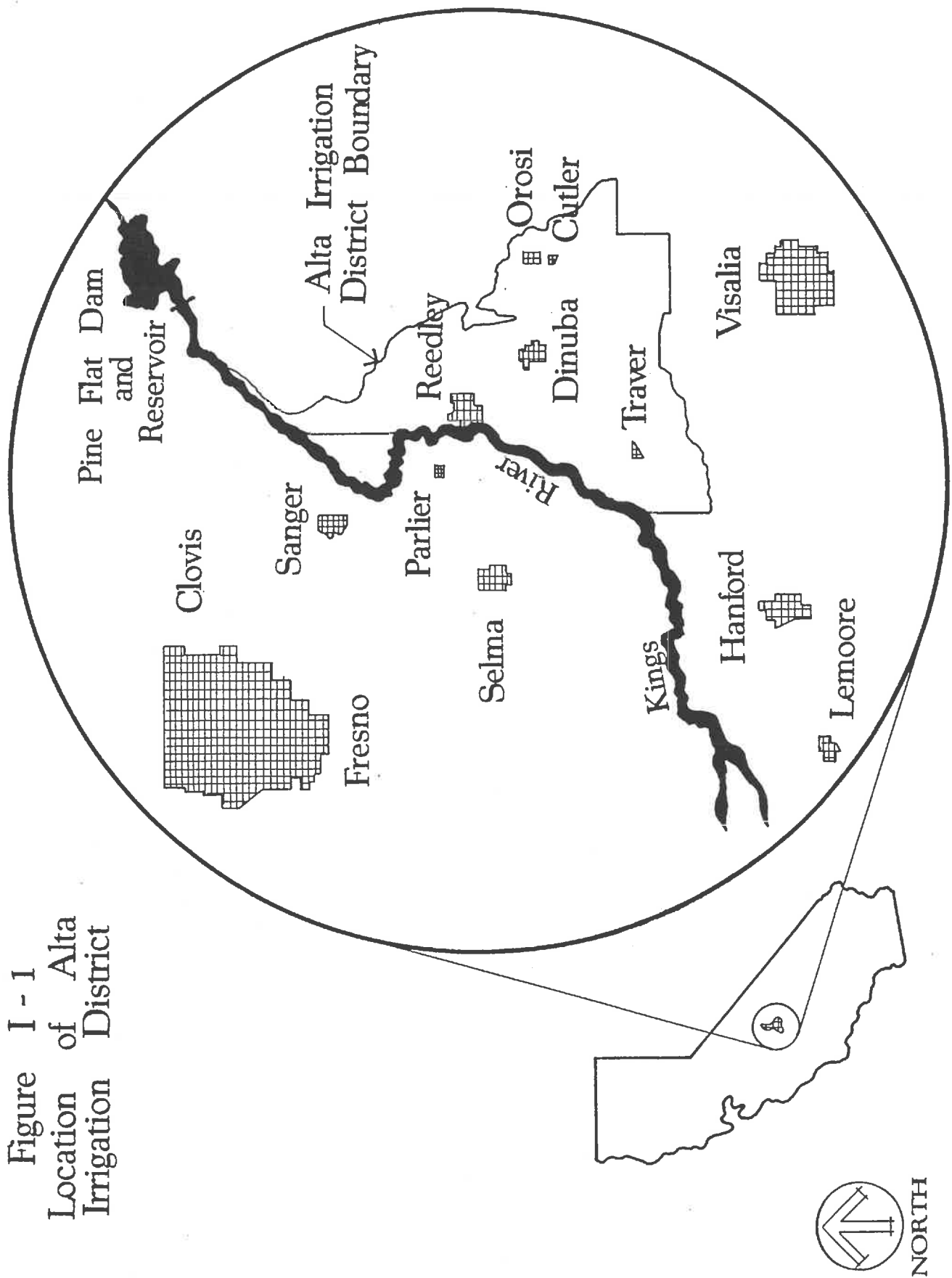
The shortfall in surface supply is routinely made up by groundwater pumping. Steady pumping over a period of several decades has resulted in serious groundwater overdraft. In periods of drought, the rate of water table decline is intensified.

During the recent consecutive dry years of 1987 through 1991, groundwater shortages have occurred in many locations throughout the district. Shortages appear to be most prevalent near the foothills (eastern boundary) where the aquifer tends to be more shallow.

In early 1991, the assistance of the Kings River Conservation District (KRCD) was enlisted to study Alta's surface and subsurface water resources. The purpose of these studies is to quantify losses of Alta's distribution system and model the underlying groundwater flow to predict the severity of future shortfalls.

The KRCD staff intends to address these topics through this Surface Water Study and a subsequent Groundwater Study. The results of the surface water analyses are an integral prerequisite to the groundwater modeling effort.

Figure I - 1
Location of Alta
Irrigation District



This study provides an estimate of the losses of Alta's distribution system. Quantified losses include seepage, evaporation, evapotranspiration of canal bank vegetation, and operational spillage (leaving the district). In addition, a water balance was done to quantify the amount of unaccounted water.

3. DISTRIBUTION SYSTEM

Alta diverts water from the Kings River at a structure known as the "Cobbles Weir" below the town of Piedra. Water diverted at this point flows down the 76 Canal to the Alta headgate. The headgate is the point at which Alta's diversion is measured.

Downstream of the headgate, water is delivered to approximately 4,000 farm turnouts through a series of canals and concrete pipelines (Figures I-2A and I-2B). The average canal width varies from 4 to over 70 feet; lengths range from 3,000 feet to nearly 18 miles (Table I-1).

The vast majority of the channels are earth-lined, with most channels having an average width of between 10 and 20 feet (Table I-2). The total length of canals and pipes scaled from district mapping was approximately 315 miles.

Alta strives to maintain a constant diversion from the Kings River and constant flows in the district's canals during the irrigation season. This helps to prevent canal overflows and to reduce the amount of operational spill that leaves the district.

During years of above average entitlement, the canals are at full capacity for the entire irrigation season. During dry years, canals in areas of lower water allotment (primarily in the southern portion of the district) do not flow during certain periods of the irrigation season. Alta is divided into zones of 100 percent, 75 percent, 50 percent, 25 percent, and 5 percent water allotment. Table I-3 gives an estimate of the percent of the season that these intermittent canals flow.

4. WATER MEASUREMENT

The flow of water in Alta's distribution system is measured in most cases by undershot gates and overflow weirs; but Parshall Flumes are used in several locations, and a current meter is used near the headgate. The head loss across the undershot gates is usually determined with permanently installed stilling wells. However, on some of the smaller gates and all of the weirs, heads are measured using hand held measuring tapes. Alta's ditch tenders and water dividers are provided with rating booklets that aid them in converting head measurements to flow rates for most flow structures within the district.

During the irrigation season, farmers order water deliveries directly from their assigned ditch tender. A farm turnout may receive water for a period of one day to several weeks per delivery cycle depending on the acreage that the turnout serves.

The flow of water through farm turnouts is measured by ditch tenders each day during delivery. The flow is estimated by measuring the head loss across a slide gate (rectangular submerged orifice) using a hand-held measuring tape and looking up the corresponding flow in a rating book. The growers arrange in advance with the ditch tenders when to open and close their valves for a delivery.

Figures I-2A and I-2B

Alta I.D. Delivery System

Please Refer to Pocket at Back of Report

Canal Name	Length (mi)	Average Top Width (ft)	Average Cross Sectional Area (sq ft)	Canal Volume (AF)	Canal Name	Length (mi)	Average Top Width (ft)	Average Cross Sectional Area (sq ft)	Canal Volume (AF)
Alta Main	8.8	72.4	245	265.3	King	4.4	13.8	19	10.1
A.B. Clark	4.4	12.4	19	8.8	Kirk	1.7	4.6	4	0.7
A.N. Smith	1.8	5.7	5	0.7	Knestric	5.6	6.2	4	2.5
A.W. Clark	2.9	8.3	9	2.6	Loper	3.2	6.3	4	1.7
Andrews	2.5	4.0	3	1.0	Lovell	2.0	5.7	5	1.1
Ballard	2.8	9.3	11	1.5	McBriar	2.0	N/A	N/A	0.8
Banks	17.7	13.2	21	44.8	McClanahan	5.9	15.1	27	18.3
Bowhay	3.1	12.6	20	7.5	Mc Gee	1.9	4.6	4	1.3
Bump & Edmiston	1.8	7.3	7	0.6	Monson	7.0	13.9	27	23.0
Button	15.0	17.7	28	50.9	Montague	1.3	4.4	4	0.5
Buttonwillow	11.0	19.9	48	60.4	Mt Campbell	3.7	12.8	20	6.4
Caesar	5.3	15.7	27	17.1	Nichols-Cann	1.9	N/A	N/A	0.5
California Vineyard	6.9	19.2	46	37.6	Nuss	1.2	N/A	N/A	0.1
Cary-Hunter	7.7	12.9	19	16.0	Orosi School House	3.2	7.5	7	2.8
Carpenter	1.2	10.9	15	1.0	Parenti	1.3	N/A	N/A	0.3
Clapp	1.5	6.1	6	0.3	Parks	1.5	7.7	9	0.9
Clements	4.0	13.5	20	9.7	Peck	0.6	N/A	N/A	0.1
Clough	3.9	10.7	14	6.8	Red Williams	1.5	16.1	16	3.3
Cross Creek W.W.	1.9	11.6	17	3.9	Reedley Main	3.0	21.5	45	16.7
Curtis Cutoff	1.5	15.0	24	2.3	Rao	1.5	4.5	2	0.4
Lower Curtis Cutoff	0.9	10.2	13	1.0	Rice-Brubaker	2.2	5.4	5	0.8
Upper Curtis Cutoff	1.0	11.0	14	0.5	Sandridge	2.9	15.4	30	5.8
Dinuba Town	8.8	13.9	24	24.5	Segrue	0.3	N/A	N/A	0.1
East Branch	15.5	42.8	123	231.5	Smith Mountain	9.3	12.8	17	17.9
East Gould	1.5	4.5	2	0.2	Sontag	6.7	9.5	12	9.3
East Reedley	5.5	17.5	46	18.1	Tout	6.0	10.2	13	8.2
East Section 20	1.2	8.3	10	1.4	Traver Creek	10.1	28.0	78	95.6
Elter	2.5	6.5	5	1.5	Traver Canal	12.3	39.4	58	86.6
Floyd	1.5	4.8	4	0.6	Uphill	0.6	N/A	N/A	0.1
Frane	1.4	N/A	N/A	0.1	Van Noy	2.2	8.9	12	3.3
Gordon	1.0	5.7	6	0.5	Waltoko	5.1	12.8	15	7.1
Grove	1.7	7.5	10	1.2	Welsse	1.0	9.1	11	1.3
Haden & Boone	2.7	6.0	6	1.3	West Gould	4.9	7.6	10	4.8
Hogan	2.1	5.4	5	0.4	West Reedley	5.6	10.6	13	7.6
Horseman	5.0	9.2	9	5.7	West Section 20	1.8	7.5	7	1.5
J. T. Williams	2.4	N/A	N/A	0.8	Wilson	10.7	16.4	31	40.1
Jack	1.2	8.0	10	1.4	Wilson Hunter	1.5	10.4	18	3.3
Kennedy School House	5.0	13.4	23	2.9	Wilson School House	3.4	11.1	16	6.2
Kennedy Waste Way	7.3	13.4	22	15.2	Windsor	1.3	N/A	N/A	0.2
					Total	316.7			1,239.1

Notes: Width and area values as N/A denote canals that are completely piped.
Width and area values are for open channel segments only.

Table I-2 Summary of Alta I.D. Delivery System		
(1) Description	Number of Segments	Total Length (mi)
Unlined Canals:		
wider than 60 feet	22	9.7
between 50 and 60 feet	8	3.3
between 40 and 50 feet	20	10.2
between 30 and 40 feet	26	15.3
between 20 and 30 feet	30	21.0
between 10 and 20 feet	219	134.3
less than 10 feet	104	52.0
Sub-total	429	245.7
Lined Canals:		
wider than 60 feet	0	0.0
between 50 and 60 feet	0	0.0
between 40 and 50 feet	0	0.0
between 30 and 40 feet	0	0.0
between 20 and 30 feet	0	0.0
between 10 and 20 feet	6	3.4
less than 10 feet	6	4.2
Sub-total	12	7.6
Pipe Lines:		
all	121	63.5
Total	562	316.7

Ditch tenders typically unlock the farmer's valves the day before delivery is to start and relock them the day after the delivery ends. Farmers operate the turnout valves themselves.

This relatively low-cost method of water delivery has worked successfully for Alta for many decades. However, some concern has arisen regarding the ability of this method to keep track of fluctuating flow rates and the starting and ending times of farm deliveries for equitable distribution of water within the district.

Table I-3 Alta I.D. Intermittent Canals		
Canal	Segment Number	Assumed Percent Operation
Banks	1 - 22	50
Banks	22 - 29	10
Button	10 - 23	50
Cary Hunter Ditch	18	50
Clough	1 - 3	10
Cross Creek Waste Way	1 - 2	10
Kennedy School House	7	50
Kennedy Waste Way	9	50
King	3 - 8	50
McClannahan	9	50
Red Williams	1 - 4	50
Sontag	4 - 7	50
Traver Canal	26 - 32	50
Traver Canal	32 - 34	10
Vanoy	2 - 4	50
Weise	1 - 2	10
Wilson School House	8	50
Notes:		
1. Canal segment number: segments defined by canal soil type, cross section, and ground water modeling element boundary (see Figures I-1A and I-1B)		

II

METHODS

1. DESCRIPTION OF DELIVERY SYSTEM

A. Field Surveys

The Alta surface delivery system was surveyed to determine its pertinent physical properties. The properties that were surveyed in the field included canal cross section, general soil type, amount of vegetation on the banks, and the presence of a lining.

Because of the large area covered by the district's facilities, it was determined to be infeasible to obtain detailed cross sections using conventional surveying methods. Instead, the cross sections were measured by stretching a fiberglass measuring tape across each section and using a surveying rod to measure the distance from the canal bottom to the tape at several points across the canal. The tape was leveled using a carpenter's level held up to the center of the tape's span.

A horizontal measure of each data point was determined from reading the tape, and the vertical component was read from the rod. In this way the general shape of each canal section was determined, but the elevation of each section relative to a known datum was not known.

Most canal cross sections were delineated with six to eight such data points. Larger channels were described with up to ten points. Very small V-shaped ditches were described with three points. Data points were taken at the apparent water line and canal bottom. For most canals, the water line was made obvious from the dead weeds left from the previous year. Wherever possible, points were taken at the top of the bank. Some canals had been recently regraded which obliterated obvious water lines. For these channels, the water line was estimated from the water stain on turnout structures or from freeboard measurements taken during the 1991 irrigation season.

Cross sections were taken at those canal locations which would provide the best representative of the particular canal segment. An attempt was made to obtain cross sections at the beginning of each canal branch or where there was an obvious change in the shape or size of the canal. As a check against measurement or transcription errors, a pair of cross sections, taken approximately 100 feet apart, were obtained at each location selected along the various canals on the distribution system.

When pipes were encountered during the field surveys, the diameter of the pipe was measured. In many cases, a canal indicated on the Alta I.D. map could not be found. In these cases, the canal was assumed to be piped.

Please note that in this report, Traver Creek is considered to lie north of Avenue 416. The portion of this channel that lies south of Avenue 416 is called Traver Canal.

B. Canal Segments

To make estimates of the losses of Alta's surface delivery system, it was necessary to divide the district's distribution system into a series of individual segments. Each segment was delineated to have a single soils group, similar cross section, and to lie within a single groundwater modeling element. Groundwater modeling elements are geographic subdivisions to be used in the Alta Groundwater Study (discussed previously). A total of 559 canal segments were used to compute the Alta's losses (Appendix A).

To compute seepage and evaporation losses, the top width of each cross section was calculated as the distance between the apparent water line points. The cross sectional area at each canal section location was calculated as the area below the apparent water line. Average top width and average cross sectional area of each canal segment was interpolated from the field survey data. The lengths of the canal segments were determined from scaling 7.5 minute U.S. Geologic Survey Quadrangle Maps.

Pipeline diameters were estimated in most cases based on the estimated flow rate for each section and an assumed maximum allowable velocity of 3 feet per second in the pipeline.

2. INFILTRATION RATES

A. Non-Steady Seepage

The seepage rate of an unsaturated soil tends to decrease as the soil approaches saturation. At some time after water is introduced to an unsaturated soil, it reaches a steady-state infiltration rate that is believed to be fairly constant over time. The amount of time that it takes for different soil types to reach steady-state infiltration can vary.

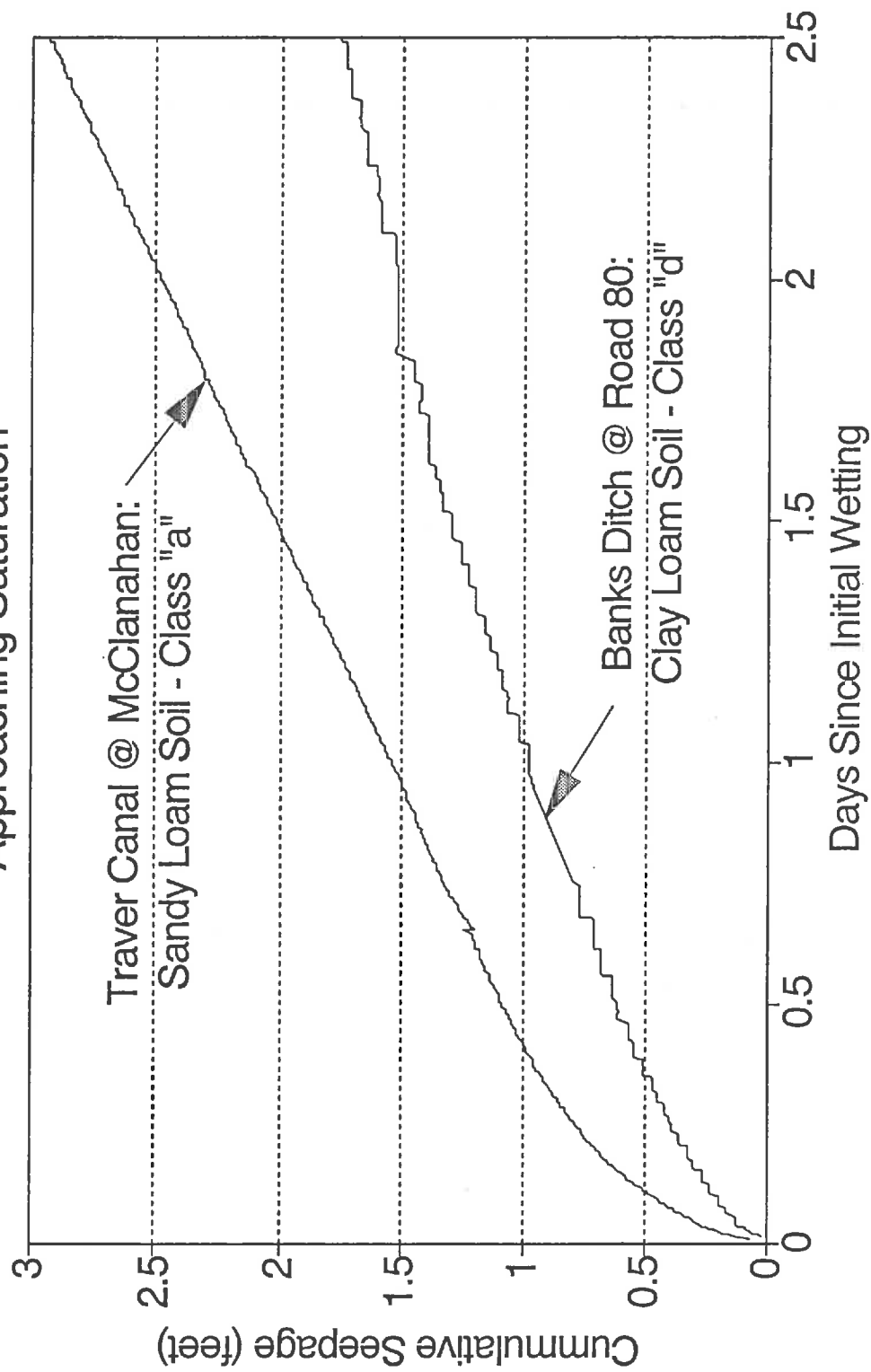
If the initial seepage rate is much higher than the steady-state rate and if the amount of time it takes to reach steady-state is long, then a large volume of water could be infiltrated during the saturation period.

The non-steady seepage rate and the saturation time of Alta's canals were estimated using double-ring infiltrometers. A double-ring infiltrometer is a device that uses an outer buffer ring and an inner measurement ring to estimate the downward rate of seepage (Jensen, 1984). These measurements were taken during the four weeks prior to the start of the 1991 irrigation season to approximate typical canal start-up conditions. Double-ring infiltrometer measurements were taken in a total of 6 canals representing course to fine textured soils.

The double-ring infiltration measurements showed that the initial soil intake rate is not significantly greater than the steady-state rate, and steady-state is achieved relatively quickly on the type of soils tested. Figure II-1 shows that the curve of cumulative seepage versus time is steep initially but flattens out in a matter of a few hours. This pattern holds true for fine and course textured soils in Alta.

It was concluded from this relationship that the amount of additional seepage that occurs during system start-up is not significant. For this reason, the quantity of additional seepage due to the initial infiltration rate was not estimated as part of this study.

Figure II-1
Infiltration of Alta I. D. Canal Soils
Approaching Saturation



B. Steady-State Seepage

Steady-state seepage is the relatively constant rate that water escapes through the sides and bottom of canals. This seepage rate can depend on many factors including soil texture, sedimentation on the canal bottom, water temperature, water velocity, the presence of a hardpan or other restrictive soil strata, and the water content of the subsurface soils.

Given the scope of this study, it was not practical to determine the effects of many of these conditions. Because of the large amount of earth-lined canals in Alta, it was determined that the most appropriate way to estimate seepage losses would be based on soil texture and the presence of confining layers.

The U.S.D.A. Soil Conservation Service (SCS) has mapped the soil in and around Alta and classified them for their use in agriculture and for their effect on storm runoff (SCS, 1940; SCS, 1971). Within the Alta boundary, there are approximately 90 different named soils (Appendix B). The SCS has described the texture and upper profile of these soils down to approximately 10 feet below the ground surface. These soils have also been classified by the SCS into four Hydrologic Soil Groups based on their permeability and tendency to yield storm runoff. The four groups are identified as *a*, *b*, *c*, and *d* with *a* being most permeable and *d* being the least permeable.

These four soil groups have been modified for this study to distinguish between soils that have significant restrictive layers within their profiles. Four additional groups were added and are identified as *a'*, *b'*, *c'*, and *d'*. A group *b'* soil for example, would have the characteristics of a group *b* soil with the exception of a restrictive layer within 10 feet of the ground surface (Table II-1). All of these additional soils were originally grouped as *c* and *d* soils because the restrictive layers produce runoff in a manner similar to the finer-textured soils. Appendix B gives a list of Alta's soils with the original and modified soil groups.

The permeability of these soils has been estimated by the SCS (Table II-1). This permeability value is defined as, "the ability of a soil to transmit air or water (SCS, 1971)." This permeability is proportional to the seepage rate of a full canal, but its magnitude is not a correct measure of that property.

To estimate the seepage rate of Alta's earth-lined canals, blocked seepage tests were conducted on three Alta canal sections varying in length from 1,600 to 3,000 feet. These tests were conducted by blocking a section of the canal and preventing any water from flowing in or out of the test section.

Alta check structures were used as the upstream and downstream dams of the test sections. The dams were sealed by using 2-inch thick check boards and sealing them with a combination of newspaper, sawdust, polyethylene sheeting, and soil. The farm and lateral valves along the test sections were sealed by filling the turnout boxes with soil.

The blocked canal tests were performed during the two weeks following August 10 which was the last day that Alta diverted water from the Kings River during the 1991 irrigation season. It was necessary to conduct these tests after the irrigation season because water was not allowed to flow through the sections during the test period and the canals were at their saturated steady-state condition.

Table II-1				
Properties of Modified Soil Groups				
(1) Modified Hydrologic Soil Group	(2) Surface Soil Permeability (in/hr) Low High		(2) Permeability Through Hard Pan (in/hr)	(2) Soil Texture
<i>a</i>	20.00	N/A	N/A	Sand & Sandy Loam
<i>b</i>	2.50	5.00	N/A	Sandy Loam & Loam
<i>c</i>	0.80	2.50	N/A	Loam & Silt Loam, Clay Loam
<i>d</i>	0.05	0.20	N/A	Clay
<i>a'</i>	5.00	10.00	0.05	Sand & Sandy Loam w/ Restrictive Layer
<i>b'</i>	2.50	5.00	0.05	Sandy Loam & Loam w/ Restrictive Layer
<i>c'</i>	0.80	2.50	0.05	Loam & Clay Loam w/ Restrictive Layer
<i>d'</i>	N/A	0.05	0.05	Clay w/ Restrictive Layer
Notes:				
1) Modified Hydrologic Soil Group based on Soil Conservation Service (SCS) soil groups with changes to distinguish hardpan soils (<i>a'</i> , <i>b'</i> , <i>c'</i> , <i>d'</i>).				
2) Properties of soils from SCS (1971).				

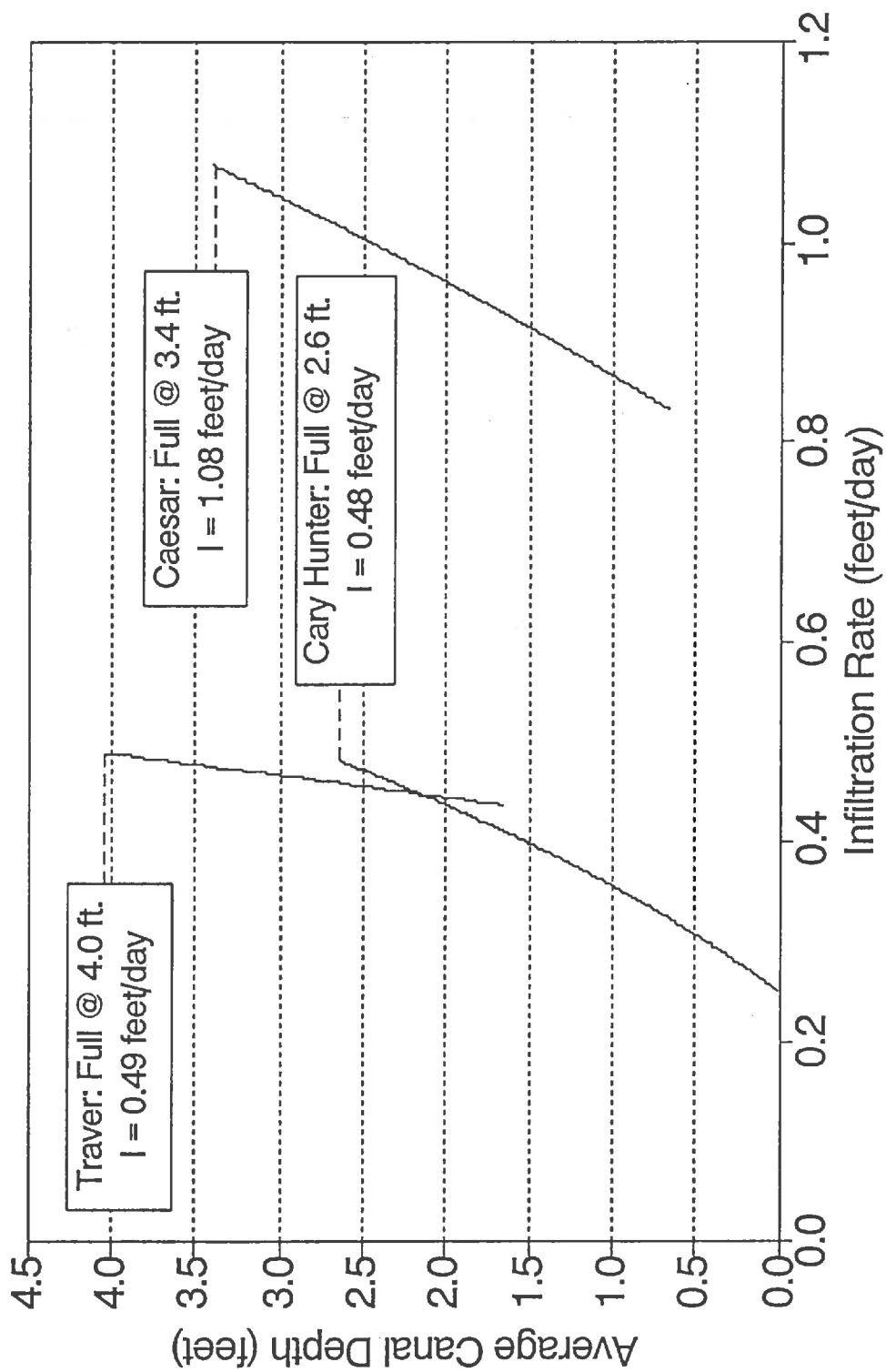
In this manner, the sections were controlled so that any water leaving a section should be the result of either seepage or evaporation. Loss from evaporation was measured using evaporation pans installed in the center of each section. The evaporation rates were calibrated with the hourly reference evapotranspiration recorded at the California Irrigation Management Information System (CIMIS) weather station located in Parlier less than 12 miles away (CIMIS, 1991).

Seepage loss was determined by measuring the depth of water every 10 minutes using a data logger and pressure transducer. The data loggers used for this study are battery operated microprocessors that record and electronically store the signal from the attached pressure transducer. The stored data was uploaded to a desktop computer for analysis. The pressure transducer is a pressure-variable electrical resistance device that is used to measure water depth.

The data loggers were checked by making manual readings of staff gages at least twice a day. Staff gages were installed at five locations along the canal sections to determine if wind effects were causing anomalies in the canal depth at the data logger. Wind was not found to appreciably affect the water depth.

Given the precision of the other inputs to seepage loss computations, it was determined that the seepage rates of the three test sections were relatively insensitive to the depth of water in the canals. Figure II-2 shows that above a depth of 1.5 feet the infiltration rates of all three sections

Figure II-2
Infiltration Rates vs Head for
Alta I.D. Blocked Canal Sections



do not change significantly. For this reason, the seepage rates of Alta's canals were calculated based on the product of the seepage rate (measured in feet per day), length (in feet), and average top width (in feet) of each canal segment.

To determine soil types, test cores were taken and particle size distribution analyses were performed for the test sections. These tests showed that the soils in these sections represented soil groups *a*, *b'*, and *c* (Table II-2).

Table II-2 Soil Textures of Alta I.D. Blocked Canal Sections						
Name	Soil Sample Depth	Percent by Weight			Texture	Modified Hydrologic Soil Group
		Sand	Silt	Clay		
Traver Canal	0-2 inches	57%	43%	0%	sandy loam	<i>c</i>
	1-2 feet	57%	43%	0%	silt loam	
Caesar Ditch	0-1.5 inches	58%	42%	0%	sandy loam	<i>a</i>
	2-3 feet	42%	58%	0%	silt loam	
Cary Hunter Ditch	0-1 feet	47%	53%	0%	silt loam	<i>b'</i>
	5-5.5 feet	61%	39%	0%	sandy loam	

The infiltration rates of the eight Alta soil groups were estimated using the data from the blocked canal tests and the SCS soil permeability values. The infiltration rates from the canal tests were assigned to the three corresponding soil groups. The infiltration rate of 1.0 foot per day from the Caesar Ditch test section was assumed to represent soil group *a*. The infiltration rate of 0.5 feet per day from the Cary Hunter Ditch and Traver Canal test sections was assumed to represent soil groups *b'* and *c*, respectively.

The infiltration rates for the remaining five soil groups were determined based on the relative proportion of the SCS permeability values (Table II-3). For example, the infiltration rate of soil group *b* was interpolated between the known values from groups *a* and *c* using the permeability values. The rate for group *d* was extrapolated in a similar manner. The rates of the remaining restrictive soils (*a'*, *c'*, and *d'*) were estimated by assuming that they would be reduced by an amount proportional to the difference between groups *b* and *b'* (Table II-3).

The infiltration rates of concrete-lined and piped canal sections were assumed to be 0.1 feet per day based on a discussion with Haight (1991).

It is recognized that this method of estimating infiltration rates is based on a small sample size, engineering judgement, and assumption. These estimates are considered to be as accurate as practicable given the scope and schedule of this project.

Table II-3 Estimated Seepage Rates for Alta I.D. Soils	
Soil Group	Assumed Infiltration Rate (feet/day)
a	1.0
a'	0.7
b	0.7
b'	0.5
c	0.5
c'	0.3
d	0.05
l (concrete lining)	0.1
p (pipe)	0.1

3. EVAPORATION

Evaporation is the method by which water is lost to the atmosphere from the canal surface. Evaporation rates are dependent on many factors including temperature, relative humidity, the size of the water body, and wind speed.

The volume of evaporation from Alta's canal surfaces was estimated using ET data obtained from the CIMIS weather station at Parlier, California. Evaporation and ET are closely related since they are both affected by the same factors.

The total evaporation loss for the two seasons analyzed was estimated for each canal segment by:

$$\text{Evap} = K \times \text{ETo} \times W \times L$$

where

Evap = seasonal canal evaporation for the segment

K = canal coefficient (assumed to be 1.0)

ETo = the sum of daily ETo for all days of the irrigation season

W = the average width of the canal segment

L = the length of the canal segment

Rainfall was not accounted for in the evaporation calculations because its quantity was assumed to be insignificant during the irrigation season. Pipelines within the district were considered to have no evaporation loss for the purpose of this study.

4. EVAPOTRANSPIRATION OF BANK VEGETATION

Evapotranspiration (ET) is the method by which water is lost to the atmosphere from water transpired by a plant and the water evaporated from the soil surface in the vicinity of the plant. The ET rate is dependent on many factors including solar radiation, temperature, relative humidity, the size and type of the plant, and wind speed.

The ET of plants along Alta's banks was estimated from an approximation of the amount of trees, brush, and weeds that extract water from the canals. For each canal segment, the width and length of a band of each vegetative type was estimated.

Only two of Alta's canals were found to have a significant band of trees. The trees along Alta Main Canal are generally larger oaks whereas those along Traver Creek are mostly smaller willows. Traver Creek was the only canal with a significant band of brush along its banks. All earth-lined canals in the system were considered to have a band of weeds along both banks at the water line.

The following equation was used to estimate ET losses for each canal segment:

$$ET = K \times ETo \times w \times l$$

where

ET = seasonal ET for trees, brush and weeds along each canal segment for the irrigation season.

K = crop coefficient (assumed to be 1.0 for this study)

ETo = seasonal reference ET, the sum of daily ETo for the number of days of active growth

w = width of the band of trees, brush or weeds

l = length of the band of trees, brush or weeds along each canal segment

A crop coefficient of 1.0 was used for all ET losses. This crop coefficient assumes that the trees, brush, and weeds consume about the same amount of water as a healthy stand of grass. A lower crop coefficient might be more accurate, but the relative magnitude of the bank ET value did not warrant additional investigation.

The value of seasonal ETo for trees and brush is the sum of the daily reference ET for each day of the irrigation season. For weeds, the length of the season was reduced by 30 days due to the fact that they take approximately 30 days to start to consume significant amounts of water. The daily ETo estimates were retrieved from the CIMIS weather station at Parlier, California (CIMIS, 1984 and 1990).

The width of the vegetation varied with each vegetative type: 4 feet for weeds, 15 feet for brush, 60 feet for trees along Traver Creek, and 80 feet for trees along Alta Main.

The length of trees and brush down the canal bank was determined from field observations and scaling of aerial photographs of the area. The length of the band of weeds was assumed to be twice the canal segment length because the weeds grow on both sides of the canals.

Pipelines and concrete-lined canal sections within the district were considered to have no vegetative losses for the purpose of this study.

5. OPERATIONAL SPILL

Operational spill is that portion of the district's surface water that flows outside of its boundary and cannot be recovered by the district. These spills can occur at the terminal ends of several of Alta's canals. The spill points are not metered but are monitored periodically by Alta's ditch tenders.

No records are kept of the quantity of the spill. The typical flow rates at spill points were estimated from recollection by Alta's canal operators for wet and dry years. It was assumed that these typical flows represent average flows leaving the district. The volume of spill was estimated as the product of the typical flow rate and the total days of operation of the district for that particular season.

6. UNACCOUNTED WATER

A district-wide water balance was used to quantify the unaccounted water volumes. Unaccounted water was estimated by the following equation:

$$\text{Unaccounted} = \text{Diverted} - \text{Losses} - \text{Delivered}$$

where

$$\text{Unaccounted} = \text{volume of unaccounted water for the season}$$

$$\text{Diverted} = \text{volume of water diverted at the Alta headgate for the season}$$

$$\text{Losses} = \text{the sum of the seasonal seepage, evaporation, bank evapotranspiration, and operational spillage (discussed previously)}$$

$$\text{Delivered} = \text{the total volume of water deliveries from Alta's records}$$

The volume of delivered water for 1984 (wet) and 1990 (dry) was determined from Alta's delivery records. Additional years of record were later examined after discovery of a significant difference between wet and dry years in the volume of unaccounted water.

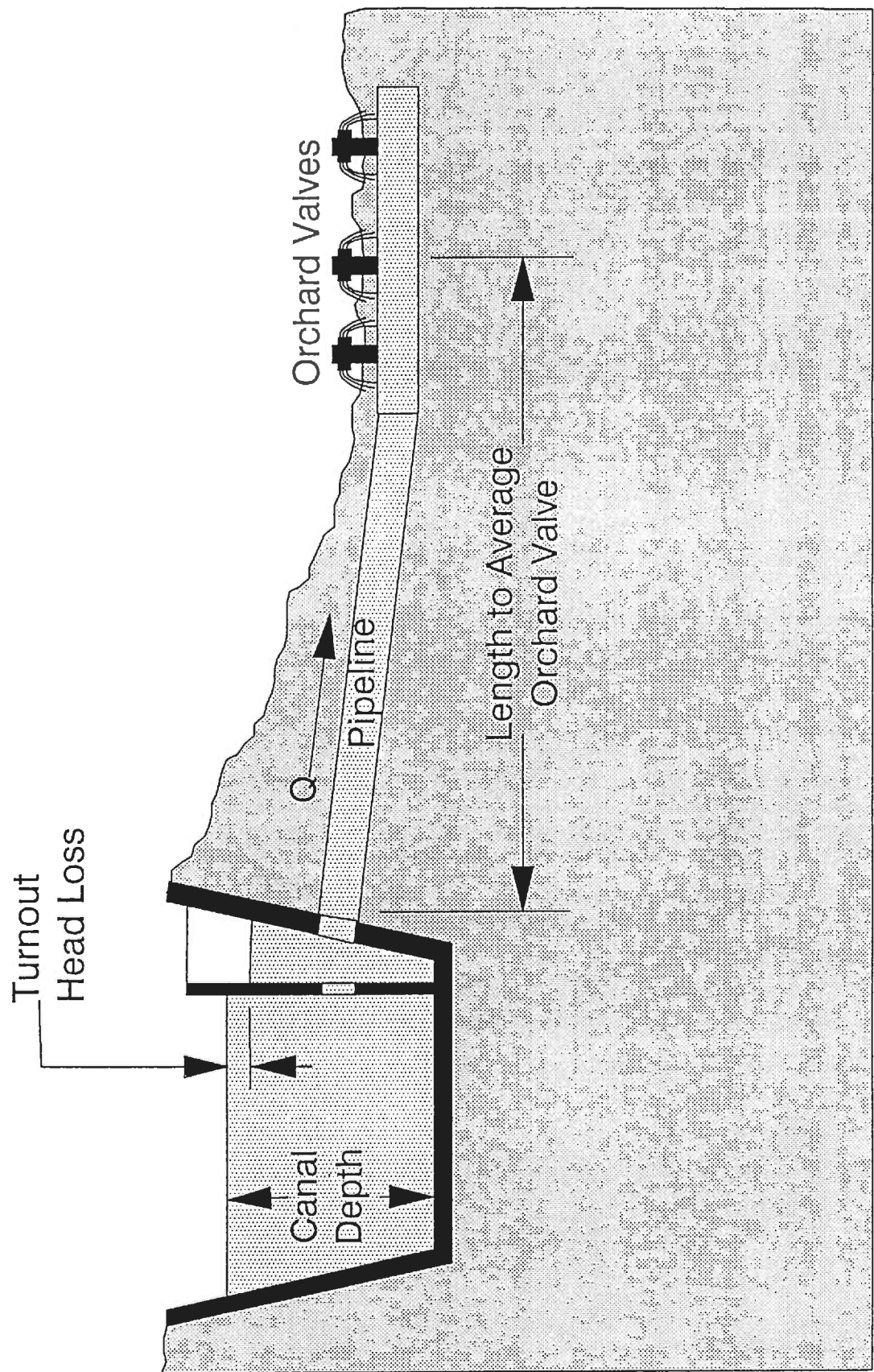
To better determine how water is delivered and accounted for in the Alta system, the operation of the district's distribution system was studied. KRCD staff accompanied three of Alta's ditch tenders and one water divider during the course of their daily duties.

Farm turnouts were monitored during the water run in order to determine typical fluctuations of flow rates during an irrigation delivery. This monitoring was done by placing data loggers on selected turnouts to measure the water surface elevations in the canal and inside the turnout box.

Measurements were taken on ten minute intervals for at least 24 hours. The elevation difference was used to calculate the instantaneous flow rate every 10 minutes and the total volume delivered during a 24-hour period.

A simplified computer model was developed to better determine the extent that district operations (primarily canal depth fluctuations) and on-farm operations affected flow through the turnouts. The model is a mathematical description of a typical Alta turnout with slide gate; screw valve, a half-mile of 12-inch diameter concrete pipe, and up to 9 orchard valves (Figure II-3). The model was developed to calculate the flow rate of this system for a base condition of 5-foot canal depth and 5 orchard valves operating at 80 percent open. The canal depth, number of operating turnouts, and opening of the turnouts was varied to determine the effects of these changes on the system flow rate.

Figure II-3
Schematic of Farm Turnout Model



III

RESULTS

1. SEEPAGE

Computations show that seepage is a significant loss of the Alta delivery system. Of the 77 canals analyzed, seepage rates varied from a negligible amount for many of the small, lined ditches to approximately 21.6 cfs for Traver Canal (Table III-1). The volume of seepage in individual canals varied from a negligible amount to volumes in excess of 6,900 acre-feet in the wet year (1984). The seepage volumes varied from negligible amounts to volumes in excess of 1,700 acre-feet in the dry year (1990).

Seepage loss in the largest canals amounted to several percent of the total head gate diversion. The total seepage for the wet and dry years is estimated at 49,230 and 13,700 acre-feet respectively. This amounts to approximately 23 percent of Alta's total diversion (Table III-1).

Both Alta's diversion and canal seepage remain relatively constant throughout the irrigation season. Therefore, the seepage can be thought of as a constant delivery of 23 percent of the district's diversion. If the district diverts 650 cfs at the head gate, approximately 150 cfs can be envisioned as flowing out through the bottom of its canals.

The canals with the greatest seepage loss are those that tend to be wider such as Traver Canal, East Branch Canal, Traver Creek, and Alta Main (Tables III-2A and III-2B). An overwhelming majority of the seepage occurs on the sandy-textured soils. The group *a* soils account for about 6 percent of the district diversion, and the group *b* soils account for almost 13 percent of the diversion (Table III-3). By contrast, all of the finer textured soils combined account for less than 5 percent of the total diversion. Appendix C gives values of seepage for each canal segment.

2. EVAPORATION

Computations show that evaporation is not a significant loss of the Alta delivery system. The total volume of evaporation lost from Alta's delivery system varied from 1,700 acre-feet in the wet year of 1984 to 430 acre-feet in the dry year of 1990 (Table III-4). These losses correspond to 0.8 and 0.7 percent of Alta's total annual diversion respectively.

Over 80 percent of the total evaporation loss occurring in Alta's delivery system is attributed to its 20 widest and longest canals (Tables III-5A and III-5B). The greater the canal's water surface area, the greater will be its evaporation; so the widest and longest canals will have the most evaporation loss.

The variance in evaporation on a daily basis was also considered insignificant. Figures III-1A and III-1B show that, even on the hottest days of 1984 and 1991, the total canal evaporation never exceeded 2 percent of the daily diversion. Appendix C gives values of evaporation for each canal segment.

Canal Name	Length Seepage		1984 Seepage		1990 Seepage		Canal Name	Length Seepage		1984 Seepage		1990 Seepage	
	(mi)	(cfs)	(AF)	% of Diversion	(AF)	% of Diversion		(mi)	(cfs)	(AF)	% of Diversion	(AF)	% of Diversion
Alta Main	8.9	11.2	3,592	1.7%	1,071	1.8%	King	4.4	3.1	979	0.5%	206	0.4%
A.B. Clark	4.4	2.5	810	0.4%	242	0.4%	Kirk	1.7	0.3	84	0.0%	25	0.0%
A.N. Smith	1.8	0.2	62	0.0%	18	0.0%	Kneetric	5.6	0.8	254	0.1%	76	0.1%
A.W. Clark	2.9	0.6	186	0.1%	56	0.1%	Loper	3.2	0.5	162	0.1%	48	0.1%
Andrews	2.5	0.4	130	0.1%	39	0.1%	Lovell	2.0	0.4	136	0.1%	41	0.1%
Ballard	2.8	0.2	79	0.0%	23	0.0%	McBrier	2.0	0.0	8	0.0%	2	0.0%
Banks	17.7	4.4	1,409	0.7%	151	0.3%	McClanahan	5.9	4.8	1,527	0.7%	446	0.8%
Bowhay	3.1	1.1	336	0.2%	100	0.2%	Mc Gee	1.9	0.2	54	0.0%	16	0.0%
Bump & Edmiston	1.8	0.2	64	0.0%	19	0.0%	Monson	7.0	3.5	1,128	0.5%	336	0.6%
Button	15.0	4.2	1,345	0.6%	281	0.5%	Montague	1.3	0.2	52	0.0%	16	0.0%
Buttonwillow	11.0	8.9	2,830	1.3%	844	1.4%	Mt Campbell	3.7	1.5	466	0.2%	139	0.2%
Caesar	5.3	4.4	1,397	0.7%	417	0.7%	Nichols-Cann	1.9	0.0	6	0.0%	2	0.0%
California Vineyard	6.9	6.1	1,938	0.9%	578	1.0%	Nuss	1.2	0.0	2	0.0%	1	0.0%
Cary-Hunter	7.7	2.8	885	0.4%	263	0.5%	Orosi School House	3.2	0.9	279	0.1%	83	0.1%
Carpenier	1.2	0.0	10	0.0%	3	0.0%	Parenti	1.3	0.0	4	0.0%	1	0.0%
Clapp	1.5	0.0	5	0.0%	2	0.0%	Parks	1.5	0.2	78	0.0%	23	0.0%
Clements	4.0	2.1	667	0.3%	199	0.3%	Peck	0.6	0.0	2	0.0%	0	0.0%
Clough	3.9	1.6	502	0.2%	15	0.0%	Red Williams	1.5	0.2	87	0.0%	10	0.0%
Cross Creek W.W.	1.9	0.4	129	0.1%	4	0.0%	Reedley Main	3.0	2.9	917	0.4%	273	0.5%
Curtis Cutoff	1.5	0.5	155	0.1%	46	0.1%	Reo	1.5	0.2	63	0.0%	19	0.0%
Lower Curtis Cutoff	0.9	0.2	73	0.0%	22	0.0%	Rice-Brubaker	2.2	0.3	99	0.0%	30	0.1%
Upper Curtis Cutoff	1.0	0.1	19	0.0%	6	0.0%	Sandridge	2.9	0.4	140	0.1%	42	0.1%
Dinuba Town	8.8	4.7	1,507	0.7%	449	0.8%	Segrue	0.3	0.0	1	0.0%	0	0.0%
East Branch	15.5	18.0	5,753	2.7%	1,715	2.9%	Smith Mountain	9.3	3.1	977	0.5%	291	0.5%
East Gould	1.5	0.1	31	0.0%	9	0.0%	Sontag	6.7	0.2	59	0.0%	14	0.0%
East Reedley	5.5	1.8	563	0.3%	168	0.3%	Tout	6.0	1.4	439	0.2%	131	0.2%
East Section 20	1.2	0.1	20	0.0%	6	0.0%	Traver Creek	10.1	12.1	3,878	1.8%	1,156	2.0%
Elter	2.5	0.1	38	0.0%	11	0.0%	Traver Canal	12.3	21.6	6,910	3.2%	1,788	3.1%
Floyd	1.5	0.1	42	0.0%	13	0.0%	Uphill	0.6	0.0	2	0.0%	0	0.0%
Frane	1.4	0.0	3	0.0%	1	0.0%	Van Noy	2.2	0.3	96	0.0%	18	0.0%
Gordon	1.0	0.1	41	0.0%	12	0.0%	Wahtoke	5.1	0.7	224	0.1%	67	0.1%
Grove	1.7	0.0	16	0.0%	5	0.0%	Weisse	1.0	0.3	80	0.0%	2	0.0%
Haden & Boone	2.7	0.4	141	0.1%	42	0.1%	West Gould	4.9	0.9	281	0.1%	84	0.1%
Hogan	2.1	0.1	37	0.0%	11	0.0%	West Reedley	5.6	1.4	442	0.2%	132	0.2%
Horseman	5.0	1.7	550	0.3%	164	0.3%	West Section 20	1.8	0.1	26	0.0%	8	0.0%
J. T. Williams	2.4	0.0	9	0.0%	3	0.0%	Wilson	10.7	7.0	2,220	1.0%	662	1.1%
Jack	1.2	0.3	103	0.0%	31	0.1%	Wilson Hunter	1.5	0.5	151	0.1%	45	0.1%
Kennedy School Hous	5.0	0.3	82	0.0%	24	0.0%	Wilson School House	3.4	0.9	287	0.1%	85	0.1%
Kennedy Waste Way	7.3	3.7	1,166	0.5%	347	0.6%	Windsor	1.3	0.0	3	0.0%	1	0.0%
Total							Total	316.7	154	49,306	23.1%	13,727	23.6%

Note: * Indicates that canal seepage is less than 0.05% of Alta's total district diversion.

Table III-2A		
Alta's 20 Canals with the Greatest Seepage in Wet (1984) Year.		
Canal Name	1984	
	(AF)	Percent of Diversion
Traver Canal	6,910	3.2%
East Branch	5,753	2.7%
Traver Creek	3,878	1.8%
Alta Main	3,592	1.7%
Buttonwillow	2,830	1.3%
Wilson	2,220	1.0%
California Vineyard	1,938	0.9%
McClanahan	1,527	0.7%
Dinuba Town	1,507	0.7%
Banks	1,409	0.7%
Caesar	1,397	0.7%
Button	1,345	0.6%
Kennedy Waste Way	1,166	0.5%
Monson	1,128	0.5%
King	979	0.5%
Smith Mountain	977	0.5%
Reedley Main	917	0.4%
Cary-Hunter	885	0.4%
A.B. Clark	810	0.4%
Clements	667	0.3%
All Other Canals	7,471	3.5%
Total	49,306	23.1%

Table III-2B		
Alta's 20 Canals with the Greatest Seepage in Dry (1990) Year.		
Canal Name	1990	
	(AF)	Percent of Diversion
Traver Canal	1,788	3.1%
East Branch	1,715	2.9%
Traver Creek	1,156	2.0%
Alta Main	1,071	1.8%
Buttonwillow	844	1.4%
Wilson	662	1.1%
California Vineyard	578	1.0%
Dinuba Town	449	0.8%
McClanahan	446	0.8%
Caesar	417	0.7%
Kennedy Waste Way	347	0.6%
Monson	336	0.6%
Smith Mountain	291	0.5%
Button	281	0.5%
Reedley Main	273	0.5%
Cary-Hunter	263	0.5%
A.B. Clark	242	0.4%
King	206	0.4%
Clements	199	0.3%
East Reedley	168	0.3%
All Other Canals	1,995	3.4%
Total	13,727	23.6%

3. EVAPOTRANSPIRATION OF BANK VEGETATION

Computations show that ET losses along Alta's canal banks are also insignificant. The total volume of water lost to bank ET from Alta's delivery system varied from 770 acre-feet in the wet year of 1984 to 80 acre-feet in the dry year of 1990 (Table III-6). These losses correspond to 0.4 percent and 0.1 percent of Alta's total annual diversion respectively.

Weeds play a much larger role in ET losses during wet years than in dry years because of the time they take to reach maturity. For shorter irrigation seasons, the mature life of grass is a

Table III-3
Alta I.D. Seepage by Soil Type

(1) Canal Segment Characteristic	Length (miles)	Seepage (cfs)	Seepage			
			1984		1990	
			(AF)	% of Diversion	(AF)	% of Diversion
a	33.81	38.3	12,242	5.7%	3,452	5.9%
b	108.16	83.2	26,592	12.5%	7,504	12.9%
c	6.16	4.9	1,569	0.7%	448	0.8%
d	38.20	2.7	846	0.4%	219	0.4%
a'	0	0	0	0.0%	0	0.0%
b'	29.58	12.2	3,910	1.8%	1,116	1.9%
c'	29.77	11.7	3,727	1.8%	864	1.5%
d'	0	0	0	0.0%	0	0.0%
p	63.41	0.9	273	0.1%	80	0.1%
l	7.61	0.5	147	0.1%	44	0.1%
Totals	316.7	154.4	49,306	23%	13,727	24%

Notes:

1. Canal Segment Characteristic delineates canal type: Concrete Lined (l) or Piped (p); or canal bottom soil type for unlined (See Table II-1).

smaller fraction of the season. For the longer, wet seasons, the grasses have more time to mature and consume water. Appendix D gives values of bank ET for each canal segment.

4. OPERATIONAL SPILL

Computations show that operational spill losses can vary from insignificant to significant amounts depending on the water year. During the wet year (1984) a total of 11,600 acre-feet of water was spilled; during the dry year (1990) only 260 acre-feet of water was spilled (Table III-7). These volumes represent 5.5 and 0.4 percent of the Alta's total diversion, respectively.

5. UNACCOUNTED WATER

The district-wide water balance computations show that unaccounted water varied from 750 acre-feet in the wet year of 1984 to 15,672 acre feet in the dry year of 1990 (Table III-8). This represents 0.4 and 26.9 percent of the diverted water respectively.

The results shown in Table III-8 made it necessary to look at records from other wet and dry years. It was found that the amount of unaccounted water varies from negligible amounts to

Canal Name	Length (mi)	Average Width (ft)	1984 Evaporation (AF)	1990 Evaporation (AF)	Canal Name	Length (mi)	Average Width (ft)	1984 Evaporation (AF)	1990 Evaporation (AF)
Alta Main	8.9	72.4	235.2	64.7	King	4.4	13.8	22.2	4.3
A.B. Clark	4.4	12.4	15.0	4.1	Kirk	1.7	4.6	2.2	0.6
A.N. Smith	1.8	5.7	1.6	0.4	Knestric	5.6	6.2	5.9	1.6
A.W. Clark	2.9	8.3	7.0	1.9	Loper	3.2	6.3	7.4	2.0
Andrews	2.5	4.0	3.6	1.0	Lovell	2.0	5.7	3.6	1.0
Ballard	2.8	9.3	3.3	0.9	McBriar	2.0	N/A	N/A	N/A
Banks	17.7	13.2	85.3	9.1	McClanahan	5.9	15.1	30.9	8.3
Bowhay	3.1	12.6	14.4	4.0	Mc Gee	1.9	4.6	1.3	0.3
Bump & Edmiston	1.8	7.3	1.6	0.4	Monson	7.0	13.9	35.4	9.7
Button	15.0	17.7	96.2	18.4	Montague	1.3	4.4	1.4	0.4
Buttonwillow	11.0	19.9	73.6	20.2	Mt. Campbell	3.7	12.8	12.0	3.3
Caesar	5.3	15.7	27.2	7.5	Nichols-Cann	1.9	N/A	N/A	N/A
California Vineyard	6.9	19.2	44.7	12.3	Nuss	1.2	N/A	N/A	N/A
Cary-Hunter	7.7	12.9	31.7	8.4	Orosi School House	3.2	7.5	8.8	2.4
Carpenter	1.2	10.9	0.9	0.2	Parenti	1.3	N/A	N/A	N/A
Clapp	1.5	6.1	0.5	0.1	Parks	1.5	7.7	2.5	0.7
Clements	4.0	13.5	19.5	5.4	Peck	0.6	N/A	N/A	N/A
Clough	3.9	10.7	15.3	0.4	Red Williams	1.5	16.1	8.8	1.2
Cross Creek W.W.	1.9	11.6	8.0	0.2	Reedley Main	3.0	21.5	23.7	6.5
Curtis Cutoff	1.5	15.0	4.1	1.1	Reo	1.5	4.5	2.2	0.6
Lower Curtis Cutoff	0.9	10.2	1.7	0.5	Rice-Brubaker	2.2	5.4	2.6	0.7
Upper Curtis Cutoff	1.0	11.0	0.4	0.1	Sandridge	2.9	15.4	7.6	2.1
Dinuba Town	8.8	13.9	40.4	11.1	Segrue	0.3	N/A	N/A	N/A
East Branch	15.5	42.8	242.0	66.5	Smith Mountain	9.3	12.8	38.7	10.7
East Gould	1.5	4.5	1.2	0.3	Sontag	6.7	9.5	21.3	4.8
East Reedley	5.5	17.5	13.7	3.8	Tout	6.0	10.2	16.5	4.5
East Section 20	1.2	8.3	3.7	1.0	Traver Creek	10.1	28.0	102.8	28.3
Eller	2.5	6.5	1.8	0.5	Traver Canal	12.3	39.4	176.0	40.6
Floyd	1.5	4.8	2.6	0.7	Uphill	0.6	N/A	N/A	N/A
Frane	1.4	N/A	N/A	N/A	Van Noy	2.2	8.9	7.0	1.6
Gordon	1.0	5.7	1.1	0.3	Wahtoke	5.1	12.8	12.8	3.5
Grove	1.7	7.5	2.6	0.7	Weisse	1.0	9.1	3.3	0.1
Haden & Boone	2.7	6.0	3.7	1.0	West Gould	4.9	7.6	8.6	2.4
Hogan	2.1	5.4	0.9	0.2	West Reedley	5.6	10.6	11.0	3.0
Horseman	5.0	9.2	16.7	4.6	West Section 20	1.8	7.5	4.8	1.3
J. T. Williams	2.4	N/A	N/A	N/A	Wilson	10.7	16.4	62.4	17.2
Jack	1.2	8.0	3.6	1.0	Wilson Hunter	1.5	10.4	5.8	1.6
Kennedy School House	5.0	13.4	1.4	0.4	Wilson School House	3.4	11.1	13.2	3.5
Kennedy Waste Way	7.3	13.4	25.6	7.0	Windsor	1.3	N/A	N/A	N/A
Total					Total	316.7		1,714.5	429.6

Note: Evaporation shown as N/A denote canals that are completely piped.

Table III-5A Alta's 20 Canals with the Greatest Evaporation in Wet (1984) Year	
Canal Name	1984 Evaporation (AF)
East Branch	242.0
Alta Main	235.2
Traver Canal	176.0
Traver Creek	102.8
Button	96.2
Banks	85.3
Buttonwillow	73.6
Wilson	62.4
California Vineyard	44.7
Dinuba Town	40.4
Smith Mountain	38.7
Monson	35.4
Cary-Hunter	31.7
McClanahan	30.9
Caesar	27.2
Kennedy Waste Way	25.6
Reedley Main	23.7
King	22.2
Sontag	21.3
Clements	19.5
All Other Canals	279.6
Total	1,714.6

Table III-5B Alta's 20 Canals with the Greatest Evaporation in Dry (1990) Year	
Canal Name	1990 Evaporation (AF)
East Branch	66.5
Alta Main	64.7
Traver Canal	40.6
Traver Creek	28.3
Buttonwillow	20.2
Button	18.4
Wilson	17.2
California Vineyard	12.3
Dinuba Town	11.1
Smith Mountain	10.7
Monson	9.7
Banks	9.1
Cary-Hunter	8.4
McClanahan	8.3
Caesar	7.5
Kennedy Waste Way	7.0
Reedley Main	6.5
Clements	5.4
Sontag	4.8
Horseman	4.6
All Other Canals	68.3
Total	429.6

values up to 30 percent of total district diversion (Table III-9). This variation appears to correspond to the type of water year. Unaccounted water is significant in dry years and negligible in average and above average water years (Figure III-2).

Fluctuations in turnout flow rate seem to be dependent on more than just canal head (Figure III-3). During a typical 24-hour period, the head in the canal varied by less than 0.3 feet while flow rate varied from 1.6 cfs to 2.0 cfs. The turnout head had many more small fluctuations than the canal head. This suggests that turnout flow fluctuations are affected more by activities occurring on the farm than by canal depth.

Figure III-1A
Alta I.D. Temperature and Canal Evaporation, 1984

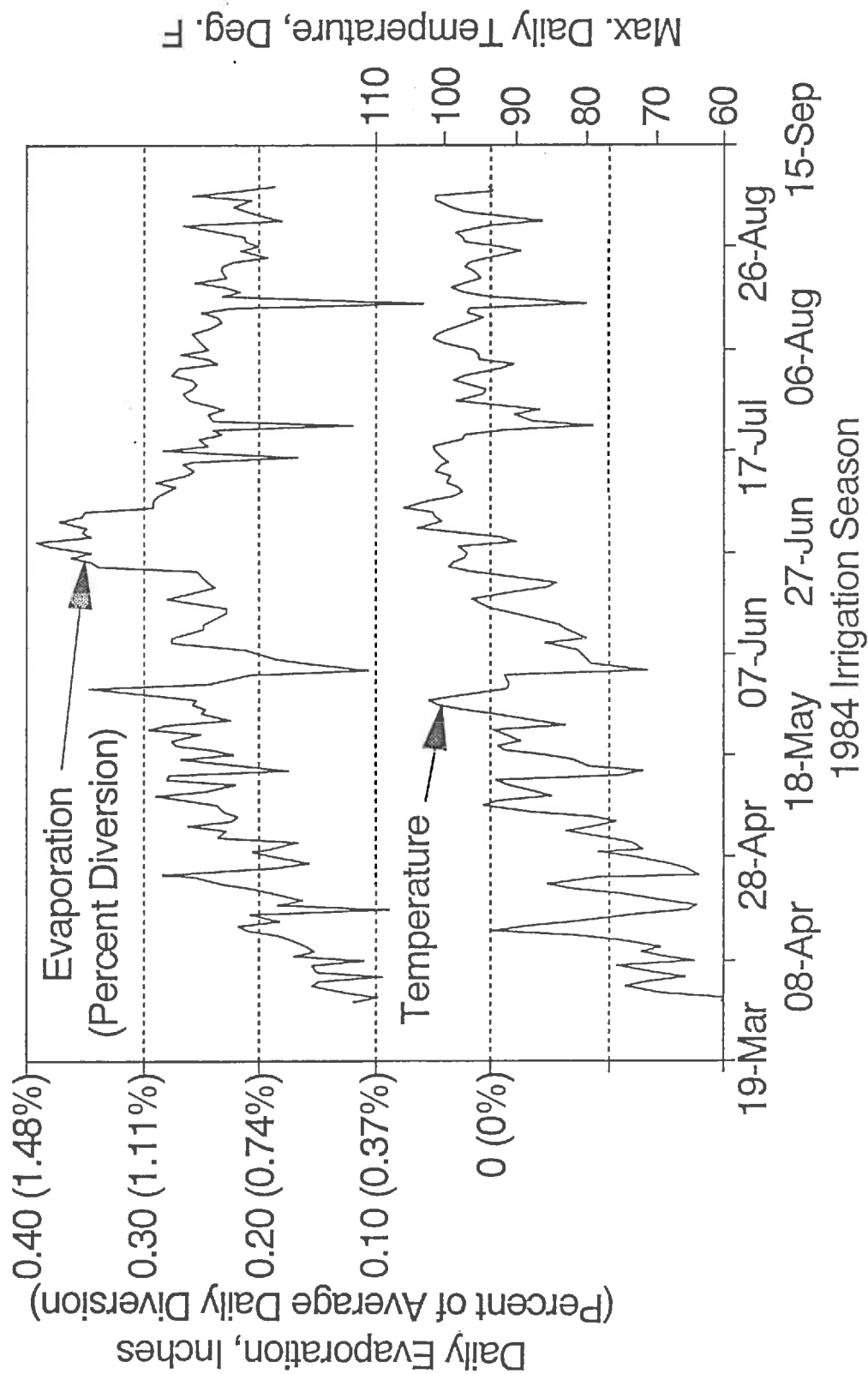
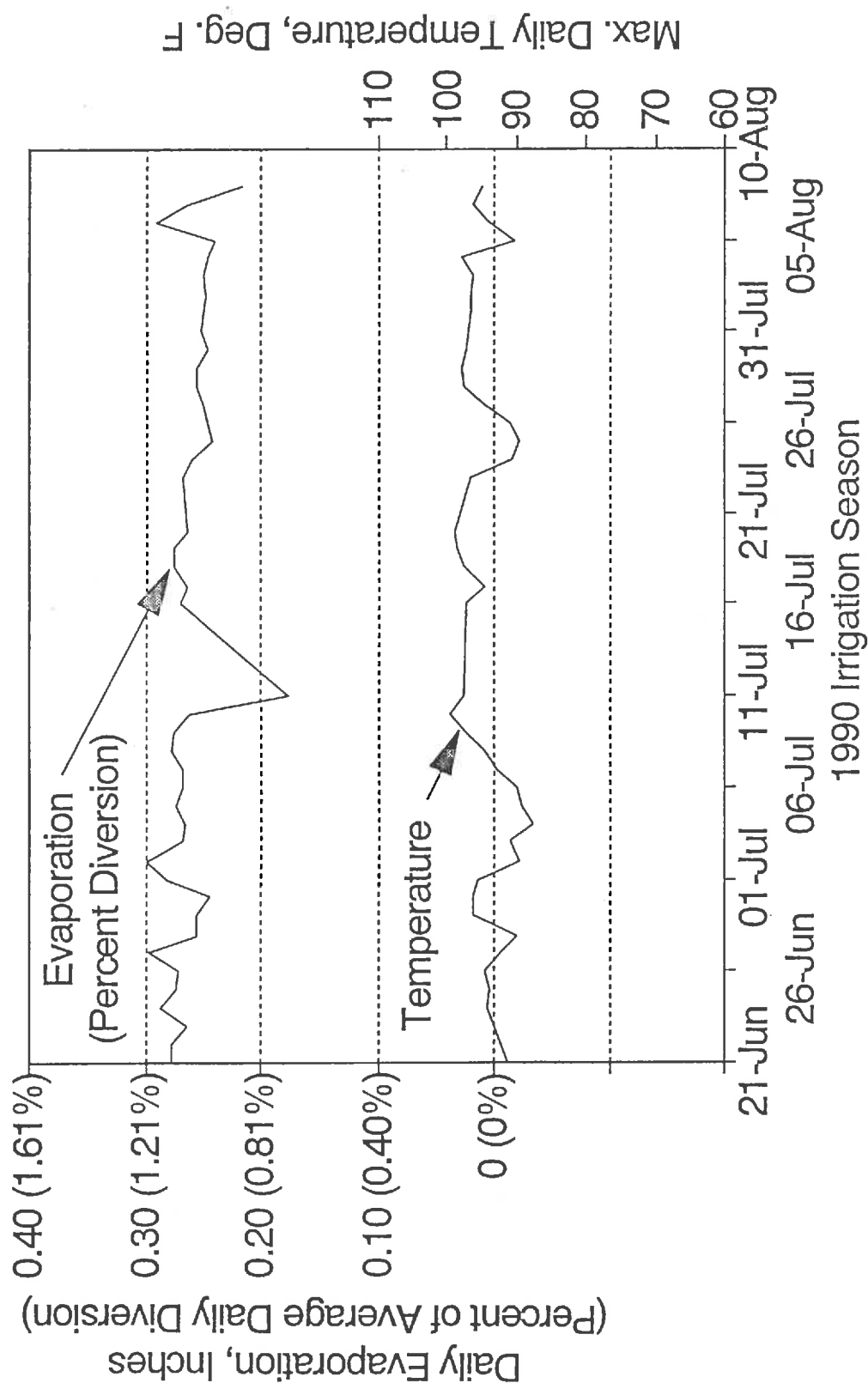


Figure III-1B
Alta I.D. Temperature and Canal Evaporation, 1990



Canal Name	Length of Canal (mi)	Length of Tree (mi)	Length of Brush (mi)	Length of Grass (mi)	1984 ET (AF)	1990 ET (AF)	Canal Name	Length of Canal (mi)	Length of Tree (mi)	Length of Brush (mi)	Length of Grass (mi)	1984 ET (AF)	1990 ET (AF)
Alta Main	8.9	1.3	0.0	17.9	61.1	12.2	King	4.4	0.0	0.0	8.8	11.1	0.6
A.B. Clark	4.4	0.0	0.0	8.9	8.3	0.6	Kirk	1.7	0.0	0.0	3.5	3.3	0.2
A.N. Smith	1.8	0.0	0.0	3.5	1.9	0.1	Krestic	5.6	0.0	0.0	11.1	6.6	0.5
A.W. Clark	2.9	0.0	0.0	5.8	5.9	0.4	Loper	3.2	0.0	0.0	6.5	8.2	0.6
Andrews	2.5	0.0	0.0	4.9	6.2	0.4	Lovell	2.0	0.0	0.0	4.0	4.4	0.3
Ballard	2.8	0.0	0.0	5.5	2.5	0.2	McBrier	2.0	N/A	N/A	N/A	N/A	N/A
Banks	17.7	0.0	0.0	35.5	44.7	1.3	McClanahan	5.9	0.0	0.0	11.8	14.2	1.0
Bowhay	3.1	0.0	0.0	6.3	7.9	0.6	Mc Gee	1.9	0.0	0.0	3.9	1.9	0.1
Bump & Edmiston	1.8	0.0	0.0	3.7	1.5	0.1	Monson	7.0	0.0	0.0	14.0	17.7	1.2
Button	15.0	0.0	0.0	29.9	37.7	1.9	Montague	1.3	0.0	0.0	2.6	2.1	0.2
Buttonwillow	11.0	0.0	0.0	22.0	25.7	1.8	Mt. Campbell	3.7	0.0	0.0	7.4	6.6	0.5
Caesar	5.3	0.0	0.0	10.5	12.0	0.8	Nichols-Cann	1.9	N/A	N/A	N/A	N/A	N/A
California Vineyard	6.9	0.0	0.0	13.9	16.2	1.1	Nuss	1.2	N/A	N/A	N/A	N/A	N/A
Cary-Hunter	7.7	0.0	0.0	15.4	17.0	1.1	Orosi School House	3.2	0.0	0.0	6.5	8.2	0.6
Carpenter	1.2	N/A	N/A	N/A	N/A	N/A	Parenti	1.3	N/A	N/A	N/A	N/A	N/A
Clapp	1.5	N/A	N/A	N/A	N/A	N/A	Parks	1.5	0.0	0.0	3.1	2.2	0.2
Clements	4.0	0.0	0.0	7.9	10.0	0.7	Peck	0.6	N/A	N/A	N/A	N/A	N/A
Clough	3.9	0.0	0.0	7.9	9.9	0.1	Red Williams	1.5	0.0	0.0	3.0	3.8	0.1
Cross Creek W.W.	1.9	0.0	0.0	3.8	4.8	0.0	Reedley Main	3.0	0.0	0.0	6.1	7.6	0.5
Curtis Cutoff	1.5	0.0	0.0	3.1	1.9	0.1	Reo	1.5	0.0	0.0	3.0	3.3	0.2
Lower Curtis Cutoff	0.9	0.0	0.0	1.9	1.1	0.1	Rice-Brubaker	2.2	0.0	0.0	4.5	3.3	0.2
Upper Curtis Cutoff	1.0	0.0	0.0	2.0	0.3	0.0	Sandridge	2.9	0.0	0.0	5.8	1.2	0.1
Dinuba Town	8.8	0.0	0.0	17.7	20.2	1.4	Segrue	0.3	N/A	N/A	N/A	N/A	N/A
East Branch	15.5	0.0	0.0	31.1	39.2	2.8	Smith Mountain	9.3	0.0	0.0	18.6	21.0	1.5
East Gould	1.5	0.0	0.0	3.0	1.8	0.1	Sontag	6.7	0.0	0.0	13.3	15.5	0.9
East Reedley	5.5	0.0	0.0	10.9	5.4	0.4	Tout	6.0	0.0	0.0	12.1	9.4	0.7
East Section 20	1.2	N/A	N/A	N/A	N/A	N/A	Traver Creek	10.1	1.2	16.0	20.2	137.8	32.7
Elter	2.5	0.0	0.0	5.1	1.9	0.1	Traver Canal	12.3	0.0	0.0	24.6	31.0	1.8
Floyd	1.5	0.0	0.0	3.0	3.8	0.3	Uphill	0.6	N/A	N/A	N/A	N/A	N/A
Frane	1.4	N/A	N/A	N/A	N/A	N/A	Van Noy	2.2	0.0	0.0	4.4	2.8	0.1
Gordon	1.0	0.0	0.0	2.0	1.3	0.1	Wahoke	5.1	0.0	0.0	10.2	6.9	0.5
Grove	1.7	N/A	N/A	N/A	N/A	N/A	Weisse	1.0	0.0	0.0	2.0	2.5	0.0
Haden & Boone	2.7	0.0	0.0	5.5	4.3	0.3	West Gould	4.9	0.0	0.0	9.9	6.6	0.5
Hogan	2.1	0.0	0.0	4.2	1.1	0.1	West Reedley	5.6	0.0	0.0	11.2	7.2	0.5
Horseman	5.0	0.0	0.0	10.0	12.6	0.9	West Section 20	1.8	N/A	N/A	N/A	N/A	N/A
J. T. Williams	2.4	N/A	N/A	N/A	N/A	N/A	Wilson	10.7	0.0	0.0	21.3	26.4	1.9
Jack	1.2	0.0	0.0	2.5	3.1	0.2	Wilson Hunter	1.5	0.0	0.0	3.1	3.9	0.3
Kennedy School House	5.0	0.0	0.0	10.0	0.7	0.1	Wilson School House	3.4	0.0	0.0	6.8	8.3	0.6
Kennedy Waste Way	7.3	0.0	0.0	14.6	13.2	0.9	Windsor	1.3	N/A	N/A	N/A	N/A	N/A
Total					316.7				2.5	16.0	592.7	770.3	80.3

Note: Length and ET shown as N/A denote canals that are completely piped or lined.

Table III-7				
Operational Spill that Leaves Alta Irrigation District for Wet (1984) and Dry (1990) Years				
Canal Name	1984		1990	
	Spill Flow (cfs)	Seasonal Spill Volume (AF)	Spill Flow (cfs)	Seasonal Spill Volume (AF)
Cross Creek Waste Way	6.00	1,916		
Traver Canal	5.50	1,756		
West Section 20	0.50	160	0.50	1.0
Clough	5.00	1,597		
Lyndecker	5.00	1,597		
Wahtoke Ditch	0.50	160	0.50	1.0
Mt. Campbell	1.00	319	1.00	2.0
Banks	1.75	559		
Orosi School House	0.75	240	0.75	
Button	7.50	2,395		
E. Branch	3.00	958		
Watoke Creek Waste Way*				
West Reedley*				
Total	36.5	11,656	2.75	262
Percent of Diversion		5.5%		0.4%
Note:				
*Spill is possible from these points but does not happen on a day to day basis.				

Results of the turnout model analysis show that opening or closing 1 out of 5 orchard valves will change the turnout flow rate as much as 18 percent (Table III-10). Similarly, a 10 percent change in orchard valve opening results in at least a 10 percent change in turnout flow rate. By contrast, it takes a 2-foot change in canal depth to cause a 10 percent change in turnout flow rate.

Table III-8
Alta I.D. Water Balance

Type of Water Source, Use, or Loss	1984 (Wet)		1990 (Dry)	
	Amount of Source, Use, or Loss (AF)	Percent of Diversion	Amount of Source, Use, or Loss (AF)	Percent of Diversion
Diversion	212,941	100.0%	58,284	100.0%
Losses				
Seepage	49,306	23.1%	13,727	23.6%
Evaporation	1,715	0.8%	430	0.7%
Bank ET	770	0.4%	80	0.1%
Spill	11,656	5.5%	262	0.5%
Sub-Total	63,447	29.8%	14,499	24.9%
Delivered	148,827	69.9%	28,137	48.3%
Unaccounted	643	0.3%	15,658	26.9%

Table III - 9
Alta I.D. Unaccounted Water from 1976 through 1990

(1) Year	Percent Of Average Kings River Runoff	Alta Head Gate Diversion (AF)	Recorded Farm Delivery (AF)	Percent Delivered	(2) Estimated Losses	Percent Unaccounted For
1975	93.6%	184,034	129,407	70.3%	30%	-0.3%
1976	31.9%	43,381	21,064	48.6%	25%	26.4%
1977	23.4%	38,721	17,441	45.0%	25%	30.0%
1978	204.1%	246,204	167,980	68.2%	30%	1.8%
1979	102.2%	181,996	124,662	68.5%	30%	1.5%
1980	180.0%	242,611	159,017	65.5%	30%	4.5%
1981	61.5%	145,581	86,654	59.5%	25%	15.5%
1982	183.8%	241,759	167,651	69.3%	30%	0.7%
1983	264.5%	203,099	135,592	66.8%	30%	3.2%
1984	116.5%	214,165	149,077	69.6%	30%	0.4%
1985	74.0%	170,826	112,489	65.9%	25%	9.1%
1986	192.8%	227,709	170,047	74.7%	30%	-4.7%
1987	46.0%	121,270	73,546	60.6%	25%	14.4%
1988	48.9%	59,118	33,305	56.3%	25%	18.7%
1989	53.5%	89,983	50,238	55.8%	25%	19.2%
1990	40.5%	58,468	28,137	48.1%	25%	26.9%

Notes:

(1) Water year (i.e. 1975 means October 1974 through September 1975).

(2) Estimated Losses Assumed:

25 percent of diverted water for dry year (Kings River runoff less than 80% of average).
30 percent of diverted water for wet year (Kings River runoff greater than 80% of average).

Figure III-2

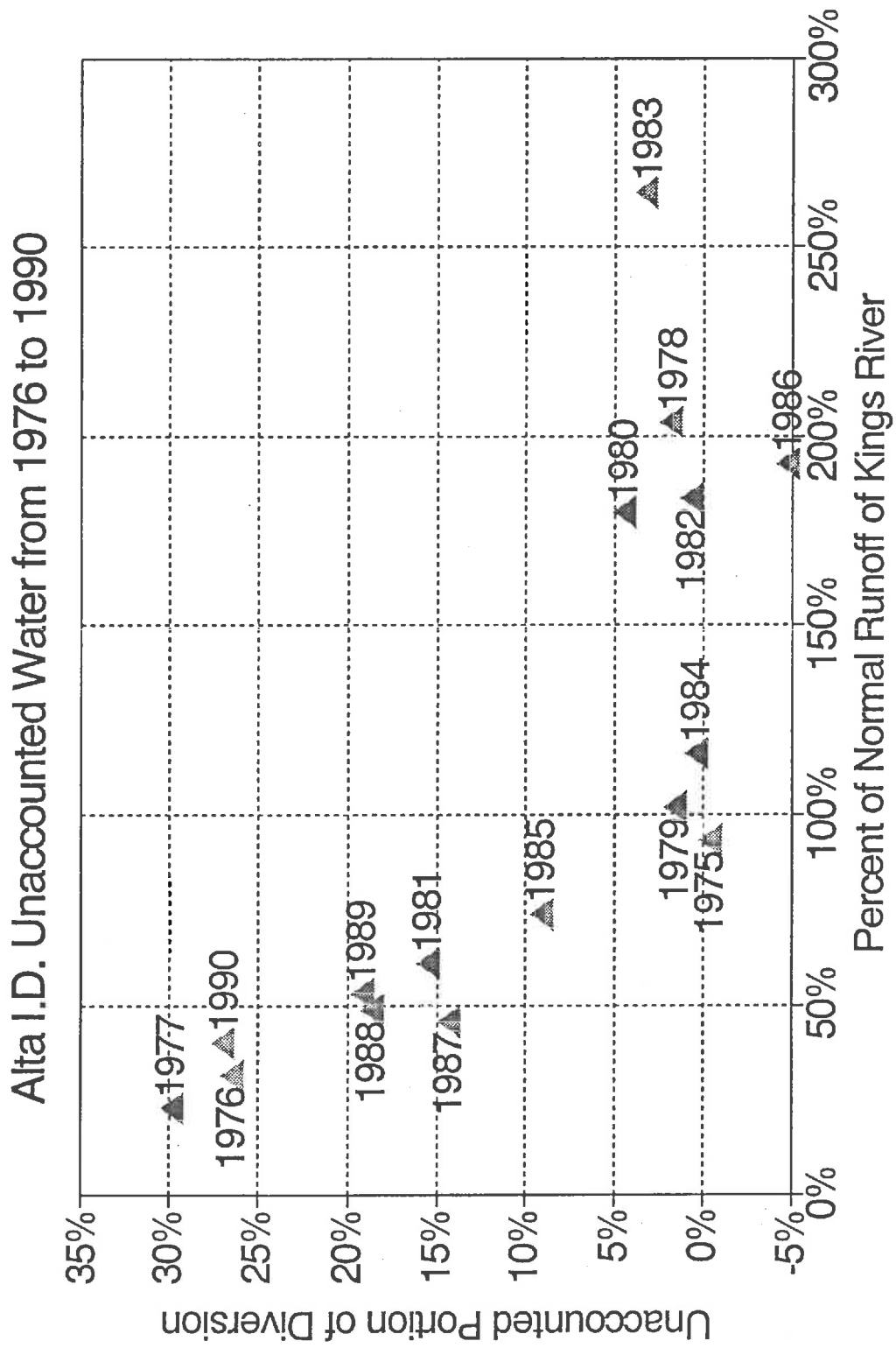
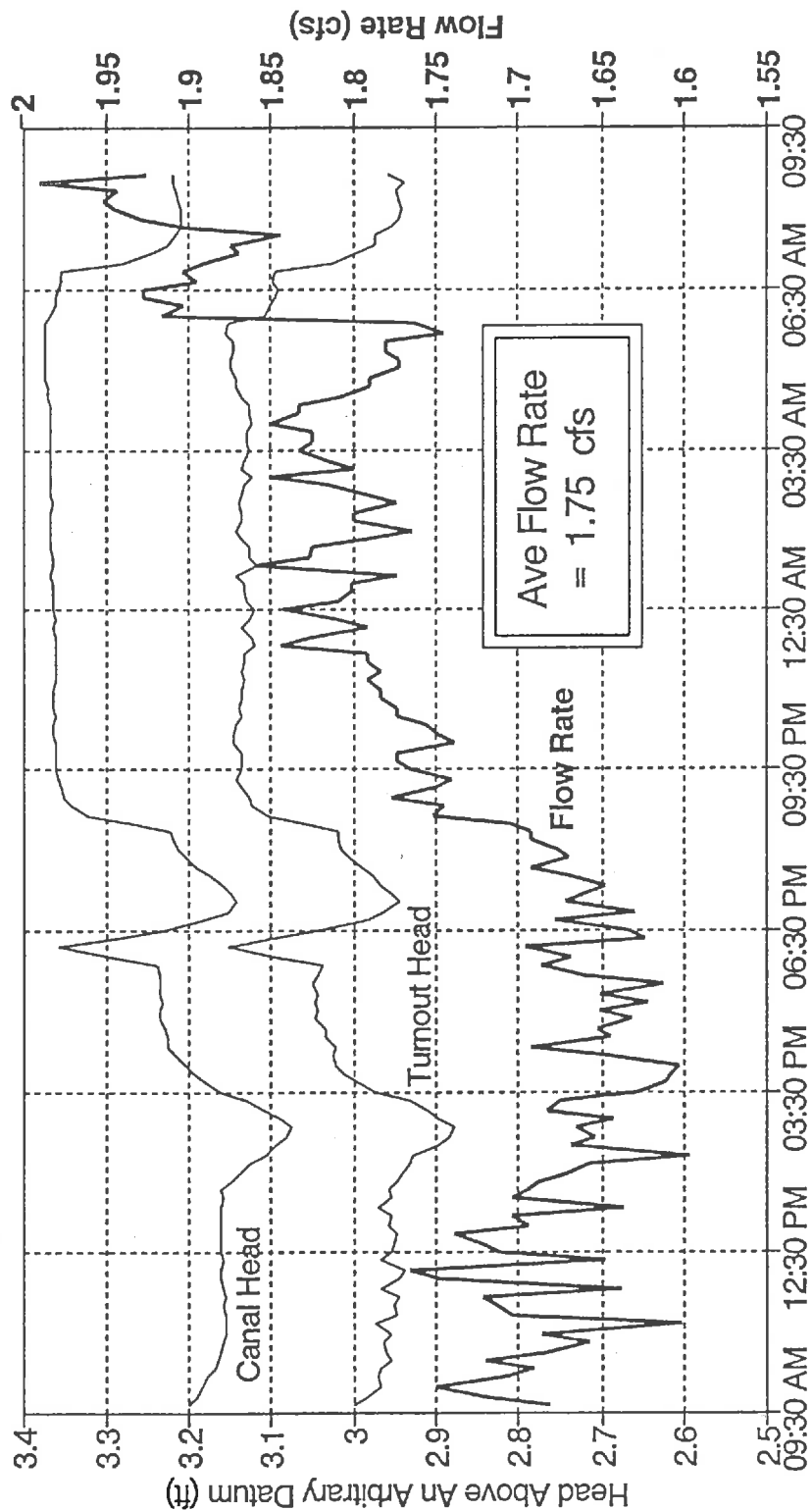


Figure III - 3
Turnout Heads and Flow Rates
(Ceasar Canal @ Rd. 40)



July 8

July 9

Table III-10 Effects of Farmer and District Operations on Turnout Flow					
Canal Depth (ft)	Number of Orchard Valves	Percent Orchard Valves Open	Turnout Head Loss (ft)	Turnout Flow (cfs)	Percent of Base Flow
Base Flow:					
5.0	5	80%	0.05	0.87	100%
Changing Canal Depth:					
3.0	5	80%	0.038	0.78	89%
3.5	5	80%	0.040	0.80	92%
4.0	5	80%	0.042	0.82	95%
4.5	5	80%	0.045	0.85	97%
5.0	5	80%	0.047	0.87	100%
5.5	5	80%	0.049	0.89	102%
6.0	5	80%	0.052	0.91	105%
6.5	5	80%	0.054	0.93	107%
7.0	5	80%	0.056	0.95	110%
Changing Number of Orchard Valves:					
5.0	1	80%	0.002	0.19	22%
5.0	2	80%	0.009	0.37	43%
5.0	3	80%	0.019	0.55	63%
5.0	4	80%	0.032	0.72	82%
5.0	5	80%	0.047	0.87	100%
5.0	6	80%	0.063	1.01	116%
5.0	7	80%	0.080	1.13	130%
5.0	8	80%	0.096	1.24	143%
5.0	9	80%	0.112	1.34	154%
Changing Amount Valves are Open:					
5.0	5	100%	0.067	1.04	120%
5.0	5	90%	0.057	0.96	110%
5.0	5	80%	0.047	0.87	100%
5.0	5	70%	0.037	0.77	89%
5.0	5	60%	0.028	0.68	78%
5.0	5	50%	0.020	0.57	66%
5.0	5	40%	0.013	0.46	53%
5.0	5	30%	0.008	0.35	40%
5.0	5	20%	0.003	0.24	27%
5.0	5	10%	0.001	0.12	14%

IV SUMMARY

Seepage is by far the most significant loss to the Alta Delivery system. Seepage accounted for approximately 77 percent and 95 percent of the total losses estimated for wet (1984) and dry years (1990), respectively (Table IV-1).

Table IV-1 Summary of Alta I.D. Distribution System Losses				
Loss	Wet Year (1984)		Dry Year (1990)	
	Percent of Diversion	Percent of Total Losses	Percent of Diversion	Percent of Total Losses
Seepage	23.1%	77.5%	23.6%	94.8%
Evaporation	0.8%	2.7%	0.7%	2.8%
Bank ET	0.4%	1.3%	0.1%	0.4%
Spill	5.5%	18.5%	0.5%	2.0%
Total	29.8%	100.0%	24.9%	100.0%

Operational spillage accounted for about 18 percent of the total loss in the wet year. The spillage is greater in wet years because more of the "tail end" canals are operated in these periods. During dry years most of the canals at the end of the system (near south and southwest boundaries) do not receive very much water because they are in low water allotment zones. For this reason, the total amount of spill from the delivery system is significantly reduced in dry years.

Evaporation and ET of bank vegetation combined accounted for less than 5 percent of the total losses. Therefore, evaporation and ET losses are not considered significant.

V

DISCUSSION

1. ACCURACY OF ESTIMATES

There are many factors affecting the losses that were estimated in this study such as soil infiltration rates, soil texture distribution, canal size, evaporation rate, et cetera. This study has made reasonable estimates of the most significant of these many factors. It is recognized that there is always some inherent error in an analysis of this type.

Given the precision of the data at hand, it is believed that these loss estimates are accurate to approximately 25 percent of their magnitude. For example, this means that the seepage estimate of 23 percent of total diversion may be as low as 17 percent or as high as 29 percent. Likewise, the evaporation estimate of 0.8 percent of total diversion may be as low as .6 percent or as high as 1.0 percent.

The magnitude of the most significant loss, seepage, will be tested and refined as part of the groundwater modeling effort discussed in Section I. The groundwater model requires calibration of inputs such as seepage and physical properties. The seepage values will be adjusted as required to calibrate the model to historical data.

2. WHY IS UNACCOUNTED WATER HIGH IN DRY YEARS?

Unaccounted water is that portion of Alta's total diversion remaining after losses and deliveries are accounted for. There is no practical way of determining exactly where this unaccounted water goes, but it can be assumed that the unaccounted water is delivered to farms without being recorded.

There is also no practical way of determining exactly why the amount of unaccounted water appears to be so high in dry years. One possible explanation is that unaccounted water is less in wet years because water measured and delivered to farms is returned to canals unmetered in the form of surface runoff.

Another possibility could be related to the inherent inexactness of the measurement methods used by Alta. There is error in any measurement. The cost of making a measurement usually increases with the accuracy of the desired result. Alta's measurements are relatively inexpensive but leave room for potentially large errors. It is possible that growers have learned to take advantage of the potential errors and perhaps do so during drought years. If this is the case, it should **not** be assumed that growers are doing anything improper or illegal, but are simply using the system to their greatest advantage.

Either or both of these explanations may explain this phenomenon, or there may be other reasons that were not apparent in this study. Regardless, this analysis implies that there may be significant error in the measurement of Alta's water deliveries. Of particular concern is whether the error is distributed evenly among Alta's water users, or if some growers are more adept at squeezing extra water from the system than others.

3. DEAD STORAGE

There is a portion of water that is diverted into Alta's system that can never be delivered to farms. This is the water that is trapped below the turnout and check structures at the end of the irrigation season. This loss was not included in other discussions because it is assumed that this water is included in the seepage estimates.

However, for the sake of discussion, the volume of dead storage is estimated to be approximately 15 percent (186 acre-feet) of the total storage in Alta's canal system (1,238 acre-feet). This dead storage volume represents about 0.1 percent of the average annual diversion. Therefore, it is not considered practical to attempt to reduce this insignificant loss.

4. IDEAS FOR REDUCING LOSSES

A. Canal Lining and Piping

Seepage losses could be reduced if canals were concrete-lined or piped. This alternative would be very expensive and could result in destroying an important source of groundwater recharge for the Alta area.

It may be possible to replace this recharge potential with artificial recharge basins. The cost of such basins was not estimated in this study, but a total basin area of between 500 and 1,000 acres would be required to replace the existing seepage of the Alta system.

A combined system of concrete-lined or piped ditches and basins would allow Alta to deliver all of its surface entitlement in dry years and recharge a portion of the entitlement in wet years.

Piping of canals would also reduce the amount of evaporation and bank ET losses. However, since these losses are less than 2 percent of the total diversion, reduction of evaporation or ET losses should not be considered a sufficient motive for piping canals.

B. Water Meters

Totalizing water meters could be installed at farmer turnouts to keep a constant count of the volume of water delivered to growers. These devices would not reduce the losses of the system, but would help ensure that water is delivered in an equitable manner.

Retrofitting turnouts can cost from \$500 to \$2,000 per turnout. The cost of meters can vary from \$1,000 to \$2,500. Other San Joaquin Valley irrigation districts have successfully rotated a few meters to several different turnouts, thereby significantly reducing costs (Rayner, 1991). The cost of purchasing 1,000 meters and retrofitting all 4,000 of Alta's turnouts could cost from \$3-million to \$10.5-million. Assuming that the meters would have a useful life of 15 years, and can be financed at an interest rate of 6 percent, the additional cost of the meters would be an average of \$1.58 to \$5.54 per acre-foot of water (based on an average entitlement of 195,035 acre-feet).

The additional annual grower assessment required to pay for meters would be an average of \$3.09 to \$10.81 per acre (based on an average assessment area of 100,000 acres).

District flow meters can also be a very valuable water management tool for Alta's growers. Many on-farm water management techniques (such as irrigation scheduling) depend on accurate and timely measurement of irrigation water applications.

C. Regulating Basins

If regulating basins were constructed at strategic locations within Alta's canal system, the amount of operational spillage that leaves the district could be reduced even in wet years.

The cost and optimum locations of such basins was not determined for this study. If the otherwise spilled water is to be used directly by farmers, it might have to be pumped from the basins, thereby increasing costs. If the water is allowed to recharge into the ground, it might be available to Alta growers in the future. The groundwater modeling effort will help to resolve this question.

Other benefits could be derived from these regulating basins. Basins could help to alleviate "tail ender" problems such as canal depth fluctuation; and they might also double as groundwater recharge facilities.

D. Reduce Bank Vegetation

The amount of trees, brush, and weed growth could be reduced along Alta's banks through off-season clearing and a more aggressive spray program. However, since the loss due to bank vegetation is estimated at less than one half of a percent, this should probably not be considered a sufficient motive for devegetation of canal banks.

5. SEEPAGE ISSUES AND UNANSWERED QUESTIONS

It is not known at this time whether water lost to seepage is a benefit to Alta constituents. It is possible that this percolated water replenishes the underlying aquifer and is available to Alta farmers for future pumping. It may be, however, that seeped water flows out from beneath Alta's growers and is not available for future use within Alta.

The groundwater modeling effort currently underway will attempt to resolve these and similar questions.