Irrigation Water Use for the Fort Lyon Canal, Southeastern Colorado, 1989-90

by Russell G. Dash

U.S. GEOLOGICAL SURVEY

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U.S. DEPARTMENT OF THE INTERIOR

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CONTENTS

FIGURES

TABLES

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
acre	0.004047	square kilometer
acre-foot (acre-ft)	1,233	cubic meter
acre-foot per day (acre-ft/d)	1,233	cubic meter per day
	0.32585	million gallons per day
acre-foot per month (acre-ft/mo)	1,233	cubic meter per month
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year
cubic foot per second (ft^3/s)	0.3048	cubic meter per second
	1.9835	acre-foot per day
foot (ft)	0.3048	meter
foot per mile (ft/mi)	0.1894	meter per kilometer
gallon (gal)	3.785	liter
gallon per minute (gal/min)	0.00379	cubic meter per minute
inch (in.)	2.54	centimeter
kilowatt-hour per acre-foot (kWh/acre-ft)	2,919	joule per cubic meter
mile (mi)	1.609	kilometer
square foot (ft^2)	0.0929	square meter

Degree Fahrenheit (°F) may be converted to degree Celsius (°C) by using the following equation:

$$°C = 5/9\ (°F - 32).$$

The following terms and abbreviations also are used in this report:

acre-foot per acre (acre-ft/acre)

acre-foot per day per mile [(acre-ft/d)/mi]

Sea Level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

GLOSSARY

Water-resource terms defined here are italicized where first used in this report. References in "Glossary" are listed in "References Cited".

acre-foot (acre-ft).—A unit for measuring the volume of water required to cover 1 acre of land (43,560 ft^2) to a depth of 1 ft, equivalent to 325,851 gal of water.

calculated time.—The time of operation of an electrical irrigation pump, at a sampling site, calculated from energy-meter readings, and expressed in hours.

canal.—An artificial waterway for the delivery of water, synonymous with ditch, in the Arkansas River Valley (Abbott, 1985).

consumptive use.—The depth or volume of irrigation, precipitation, and stored soil moisture water that is no longer available for immediate use because it has been directly evaporated from fields, transpired through the physiological functioning of crops, or is used directly in the building of plant tissue. Consumptive use does not include water used for leaching of salts, for protection against frost, or for prevention of wind erosion.

conveyance loss.—Water that is lost in transit by seepage, evaporation, or leakage between the point of withdrawal and the point of use. Seepage and leakage from an irrigation canal, for example, may percolate to a ground-water source and be available for further use.

crop acreage.—The acreage where irrigation water is applied to grow crops. Fallow land and irrigated acreage that contains unknown crops are excluded from crop acreage.

crop irrigation requirement.—The depth or volume of irrigation water, exclusive of effective precipitation, that would be consumptively used for crop production, if each crop were provided with a complete water supply.

diverts or diversion.—"***removing water from its natural course or location, or controlling water in its natural course or location, by means of a ditch, canal, flume, reservoir, bypass, pipeline, conduit, well, pump, or other structure device***" (Radosevich and others, 1975).

effective precipitation.—The portion of a rainfall event that is available to meet the evapotranspiration needs of the crop during the growing season.

fallow land.—Acreage that may be plowed to remove weeds and conserve soil moisture, but is left idle without marketable crop during a growing season. This acreage may be irrigated once or twice during the growing season to maintain a vegetative cover to decrease wind and water erosion of the surface soil.

flood irrigation.—The application of irrigation water where the surface of the soil is covered with ponded water by flooding open field ditch systems (furrows, corrugations, or borders) and continuous area flooding of alfalfa hay, pastures, and grain crops. The reported farm efficiency of flood irrigation under the Fort Lyon Canal averages about 75 percent, and total irrigation efficiency of the system is about 47 percent (Tipton and Kalmbach, Inc., 1983).

ground-water irrigated cropland.—The acreage where ground-water withdrawals are applied to grow crops. Ground-water irrigated cropland is estimated for each canal division by assuming that a maximum of 320 acres can be irrigated by each active ground-water pump. However, total ground-water acreage is limited to the maximum irrigated acreage available within the division.

ground-water withdrawal.—All water removed from subsurface sources for use as irrigation water, specifically, water located in the saturated soil zone. Ground-water withdrawals from springs are not considered in this report.

irrigation water use.—The controlled application of water on arable lands to supply the water requirements not satisfied by rainfall, for the growing of crops and pastures, and to maintain vegetative cover on fallow lands.

kilowatt-hour (kWh).—A unit of energy equivalent to one thousand watt-hours.

lateral.—A side ditch or conduit connected to the main canal that is used to deliver irrigation water to the farms and fields.

metered time.—The time of operation of an electrical irrigation pump, at a sampling site, measured using electronic running-time meters, and expressed in hours.

Parshall flume.—A specially shaped open-channel flow section with a converging entrance, a parallel-walled throat, and a diverging outlet that is installed in a canal or lateral to measure the rate of flow of water.

seepage.—The slow movement of water by gravity through the porous soil medium. In this report, seepage in the unlined main canal generally percolates under free-draining conditions through an unsaturated soil zone.

sluiceway.—A man-made water channel that is used to remove some of the sand and other suspended debris in river water before diversion into the main canal.

surface-water irrigated cropland.—The acreage where surface-water withdrawals are applied for the consumptive use of vegetation. Fallow land and acreage of unknown crop use are included, but the non-cropland acreage that is used for rangeland, structures, and right-of-ways is excluded.

surface-water withdrawal.—Any water diverted from open bodies of water, such as rivers, canals, and reservoirs, for irrigation use. Surface water removed from ponds and tail-water pits are not considered in this report.

wasteway.—A diversion structure and conduit that enables excess irrigation water to be removed from the main canal. Commonly used to maintain the correct flow of decree surface water in the main canal during periods of flow fluctuation on the Arkansas River but also used to protect the canal from flood waters.

water right.—Legal right to use a specific quantity of water, on a specific time schedule, at a specific place, and for a specific purpose; "***a right to use in accordance with its priority a certain part of the waters of the State by reason of appropriation of the same***" (Radosevich and others, 1975). A direct-flow water right requires that the diverted water be put to immediate beneficial use, as opposed to a storage-flow water right, which allows storage of a set volume of diverted water for use at a later time.

water use.—In a restrictive sense as used in this report, the term refers to water that is used by humans for a specific purpose, such as for irrigation. More broadly, water use is a general term that pertains to human's interaction with and influence on the hydrologic cycle, and can refer to any facet of the water-use cycle, including water source, water use, and water disposition (Litke and Appel, 1989).

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By Russell G. Dash

Abstract

Water-use information is needed for irrigated farmland in the Arkansas River Valley of southeastern Colorado because of continuing changes in the sources and patterns of agricultural water use. The semiarid land in the area has a lengthy history of agricultural water use that dates back to the 1880's. In 1989, the U.S. Geological Survey, in cooperation with the Bent County Board of County Commissioners, began a study to evaluate irrigation water use quantitatively for about 91,630 acres of farmland irrigated from the 103.7-mile-long Fort Lyon Main Canal. This report provides information from 1989 and 1990 for four hydrologic components of irrigation water use: Surface-water withdrawals, conveyance losses, ground-water withdrawals, and estimates of theoretical crop consumptive use.

Surface-water withdrawals constituted about 85 percent of the total irrigation withdrawals supplied to the five divisions of the Fort Lyon Canal system during the 2 years of the study. Surface-water withdrawals for the Fort Lyon Canal were 211,150 acre-feet (about 2.3 acre-feet per acre) during 1989 and 202,000 acre-feet (2.2 acre-feet per acre) during 1990. The largest monthly surface-water withdrawals occurred during May through August in each canal division. Of the total surface-water withdrawals, about 81 percent was supplied by diversion from the Arkansas River and about 19 percent was supplied by diversion from off-stream reservoir storage.

Conveyance losses occurred during the transport of irrigation water in the Fort Lyon Main Canal and likely constituted a large loss from the surface-water withdrawals. Daily mean discharge data indicated that conveyance losses were larger when a high-water stage was present in the canal. Conveyance losses were the largest in the La Junta Division of the canal (as much as 72 (acre-feet per day) per mile) and generally decreased in the downstream canal divisions. A maximum loss of 432 acre-feet per day of surface water was measured in the La Junta Division, and a maximum gain of 157 acre-feet per day of surface water was measured in the Limestone Division during 1990.

Ground-water withdrawals constituted about 15 percent of the total irrigation withdrawals supplied to the five canal divisions during the 2 years of the study. Ground-water withdrawals for the Fort Lyon Canal system were estimated to be 38,890 acre-feet (about 0.8 acre-foot per acre irrigated by ground water) during 1989 and 33,970 acre-feet (about 0.7 acre-foot per acre irrigated by ground water) during 1990. The annual ground-water withdrawal ranged from 106 to 268 acre-feet per well per year at the irrigation wells that were measured in the study area.

Total theoretical crop consumptive use was estimated to be 227,530 acre-feet (about 2.7 acre-feet per acre of cropland) during 1989 and 251,130 acre-feet (about 2.9 acre-feet per acre of cropland) during 1990. Effective precipitation supplied an average of about 24 percent of the total theoretical crop consumptive use during the study period. The total theoretical crop irrigation requirement needed from irrigation withdrawals was 172,100 acre-feet (about 2.0 acre-feet per acre of cropland) during 1989 and 190,050 acre-feet (about 2.2 acre-feet per acre of cropland) during 1990.

Total acreage irrigated by the Fort Lyon Main Canal was 91,580 acres in 1989 and 91,670 acres in 1990. Similar crops were cultivated in the five canal divisions during both years and generally included alfalfa (about 61 percent of the irrigated acreage), sorghum (about 13 percent), corn (about 9 percent), wheat (about 6 percent), pasture (about 2 percent), and spring grains (about 1 percent). Fallow land (about 6 percent) and the land acreage of unknown crop use (about 1 percent) composed the remaining irrigated acreage in the study area (total acreage does not equal to 100 percent because of independent rounding).

INTRODUCTION

Irrigation water use accounts for 60 percent of all *water use* in Colorado and 72 percent of all water use in the Arkansas River Valley (Litke and Appel, 1989). Since the 1880's, irrigation of cropland has accounted for most of the total water use within the study area (fig. 1). The Fort Lyon Main *Canal*, which *diverts* surface water from the Arkansas River about 4 mi upstream from La Junta, is the largest canal in southeastern Colorado, irrigating about 91,630 acres of land. Because of the inadequate and unreliable amount of surface water available for crops in the study area, the ground water in the shallow valley-fill aquifer underlying the Arkansas River and some of the larger tributaries to the river was developed as a supplemental source of irrigation supply by individual canal shareholders from the 1930's through the early 1970's.

The economy of the study area primarily is agricultural; alfalfa, sorghum, corn, wheat, pasture, and spring grains are the principal crops. Successful crop production of alfalfa hay, a crop of great monetary value in the area (Colorado Crop and Livestock Reporting Service, 1990), generally requires about 40 in. of irrigation water for *consumptive use* during the normal growing season between March and November (U.S. Soil Conservation Service, 1988). Because the annual precipitation ranges from about 11 in. near La Junta to about 14 in. near Lamar, substantial irrigation is required for successful crop production in the area.

Rapid changes in the sources and patterns of agricultural water use occurred in the area during the 1970's. In 1972, state rules and regulations on ground-water pumpage were adopted to help limit the depletion of surface-water flow in the Arkansas River Valley. Since 1975, operation of the Fryingpan-Arkansas project (U.S. Bureau of Reclamation, 1975) has provided imported transmountain water and additional reservoir storage to water users in the valley. These changes in water sources have affected the timing and availability of the agricultural water supply during the irrigation season in the study area.

In 1989, the U.S. Geological Survey, in cooperation with the Bent County Board of County Commissioners, began an investigation of water use in the area irrigated by the Fort Lyon Canal system to better quantify *surface-water withdrawals, conveyance losses, ground-water withdrawals*, and theoretical crop consumptive use. Estimates of these four components of irrigation water use are needed by the many water users to wisely manage and use the limited water resources in the area.

Purpose and Scope

This report describes four components of irrigation water use for the Fort Lyon Canal system. The following are quantified by canal division in the report:

1. Surface-water withdrawals;
2. Conveyance losses in the main canal;
3. Ground-water withdrawals; and
4. Theoretical crop consumptive use.

The Fort Lyon Canal is an irrigation system that includes a direct-flow *water-right* system and a storage-flow water-right system. This report concentrates on the direct-flow water-right system, shown as the Fort Lyon Main Canal in figure 1, hereafter called the Fort Lyon Canal. In this report, the irrigation season is defined as being from March 15 through November 15, which generally corresponds to the period of operation of the main canal. The streamflow-gaging stations shown in figure 1 and the reservoir-inflow locations are referenced in canal miles downstream from the second *diversion* dam of the Fort Lyon Canal. The canal locations presented in this report were provided by the Fort Lyon Canal Company and verified by U.S. Geological Survey personnel, using a vehicle odometer, to be within about 2 percent of the reported location.

From January 1989 through December 1990, streamflow data from four streamflow-gaging stations on the Fort Lyon Canal (Ugland and others, 1990, 1991) were analyzed and were supplemented by streamflow data from three additional streamflow-gaging stations used during the operation of the Fort Lyon Canal system (table 4 and tables 8–10) to quantify surface-water withdrawals. (Tables 8–10 are in the "Supplemental Data" section at the back of this report.) Conveyance-loss investigations that included 73 percent of the Fort Lyon Canal began during the 1989 irrigation season, and conveyance losses were determined periodically until the completion of the 1990 irrigation season. Conveyance losses were estimated using the difference in streamflow between the gaging stations during time periods when there were no *lateral* diversions for irrigation within a particular canal division. The discussion of conveyance losses is limited to a presentation of the range of estimates that were determined for the main canal from the existing daily conveyance-loss data. Ground-water withdrawals were determined for 43 percent of the irrigation wells in the study area from January 1989 through December 1990 using power-consumption techniques described by Hurr and Litke (1989). Estimates of the-

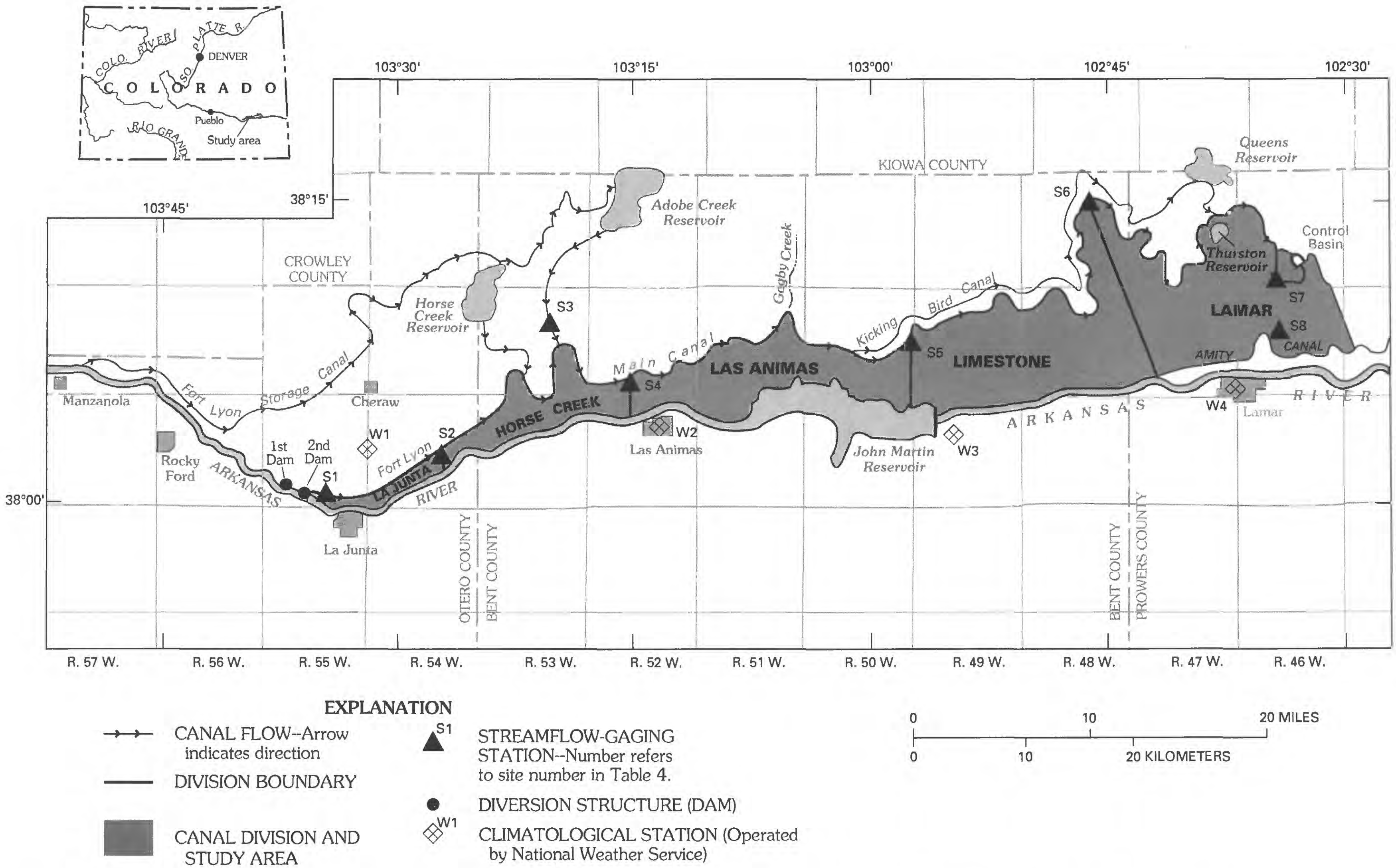


Figure 1. Location of the study area, canal divisions, streamflow-gaging stations, and climatological stations on or near the Fort Lyon Canal system.

oretical crop consumptive use were prepared using the modified Blaney-Criddle method (U.S. Soil Conservation Service, 1970) and irrigated acreage and crop data provided by the U.S. Agricultural Stabilization and Conservation Service (written commun., 1989, 1990). Field verification of irrigated acreage and crops was done before and during the 1989 and 1990 irrigation seasons. Acreage data are used in the estimation of the average water use for the irrigated land and specific crop types in each canal division. These include *surface-water irrigated cropland* for surface-water averages, *ground-water irrigated cropland* for ground-water averages, and *crop acreage* for the theoretical crop consumptive-use averages.

Description of the Study Area

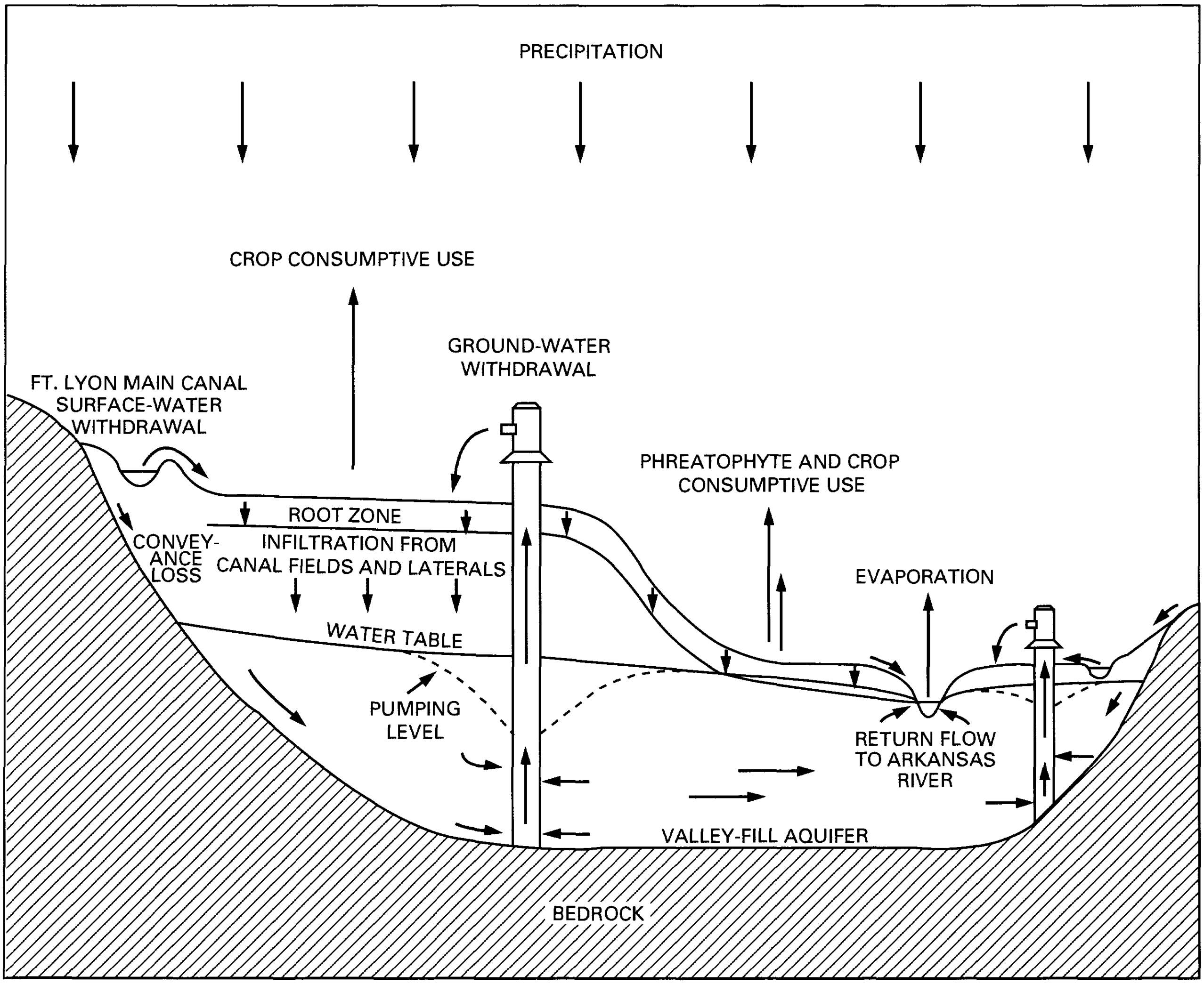
The study area (fig. 1) consists of the 103.7-mi-long Fort Lyon Canal and all the lands irrigated by water from the canal. The geomorphic structure from west to east near the study area is bordered on the north by gravel-capped terraces, low-lying mesas, and undulating uplands that slope gradually toward the Arkansas River. The elevation at La Junta (fig. 1), located near the western side of the study area, is about 4,200 ft; at Las Animas, about 3,890 ft; and at Lamar, located near the eastern side of the study area, about 3,620 ft. The Fort Lyon Canal spans valley-fill deposits for about the first 3 canal miles, slowly leaves the river flood plain in the next 12 mi, and continues onto a long, intermediate river slope that is located between the river terrace and the uplands to the north. As the canal continues eastward, the terrain changes near canal mile 30 from long river slopes to a gradually sloping upland for the remaining 74 canal miles. The brown and reddish-brown clay loams to silty clay loam surface soils on about 95 percent of the lands being farmed and irrigated in the study area developed under semiarid climatic conditions from alluvial, aeolian, and residual sources (U.S. Department of Agriculture, 1926). The geology and historical water-resources development in much of the study area have been described by Voegeli and Hershey (1965) and Weist (1965).

A diagram of the hydrogeologic setting in the study area (fig. 2) depicts that irrigation water is distributed to cropland from the Fort Lyon Canal and from irrigation wells penetrating the valley-fill aquifer. Irrigation water is distributed by laterals from the canal to the fields through dirt and concrete ditches and through closed pipe systems. Irrigation practice primarily is by *flood irrigation* of well-established fields on farms that range in size from about 40 to 960 acres. The crop root zone generally is deep and well drained making the gently sloping land suitable for general farming and grazing of livestock. Conveyance losses from the Fort Lyon Canal and from applied irrigation water that is not evaporated or is not transpired by phreatophytes or crops ultimately recharge the valley-fill aquifer, which is hydraulically connected to the Arkansas River (Moulder and others, 1963).

Climate data obtained from four National Weather Service (climatological) stations in Otero (site W1, La Junta 4 NNE), Bent (site W2, Las Animas; site W3, John Martin), and Prowers (site W4, Lamar) Counties (fig. 1, table 1) during 1989 and 1990 are presented by month in figure 3. Site W3, John Martin, did not have a complete temperature record for 1989 (table 1) so this site was not used in the data analysis and is not shown in figure 3. Normally, about 90 percent of the annual precipitation falls during the growing season between March and September, primarily during brief, but intense, thunderstorms. These convective storms often deliver large quantities of rainfall to small localized sections in the study area. Extreme events, including hail storms, often occur when the convective storms are combined with advancing frontal storm systems. Although the monthly air temperature varies greatly throughout the year (fig. 3), the annual mean air temperature seldom varies more than a couple of degrees (table 1) in the study area. Summer days generally are hot and windy, resulting in large evaporation rates. Summer nights are relatively cool as is characteristic of the semiarid climate in the area. From 1942 through 1978, free-water surface evaporation rates were measured during April through October near John Martin Reservoir (site W3) (fig. 1), and these evaporation rates averaged about 67 in. a year.

Description of the Irrigation System

The Fort Lyon Canal Company owns and operates the Fort Lyon Main Canal (fig. 1), through which direct-flow river water is delivered to shareholders, and the Fort Lyon Storage Canal, through which river water is delivered to two large off-stream storage reservoirs that also are owned and operated by the canal company. However, no lands are irrigated directly from the storage-canal system. For the interested reader, much of the history of the Fort Lyon Canal from 1860 to 1906 is described by Tipton and Kalmbach, Inc. (1983).



Not to Scale

Figure 2. Hydrogeologic setting in the study area near the Fort Lyon Canal (modified from Moulder and others, 1963, p. 4).

The Fort Lyon Canal generally is located along the northern boundary of the valley-fill aquifer of the Arkansas River and has an average grade of about 2.5 ft/mi. The width of the U-shaped cross section of the canal varied with location on the Fort Lyon Canal, ranging from 21.5 to 76.0 ft and averaged 51.5 ft at 33 locations used during canal discharge measurements. The composition of the canal bed generally consists of shifting sand and gravel on the canal bottom and sand and mud (silt and clay mixture) on the lower side slopes with brush and grass vegetation near the top of the canal cross section. The bottom of the canal is a veneer of sand only a few feet deep and is not necessarily the same lithology as the underlying material. The Fort Lyon Canal is 99-percent unlined and has numerous control, conveyance, and storage structures situated along its 103.7-mi length.

The two Fort Lyon Canal diversion dams (fig. 1) are located on the north bank of the Arkansas River. At the first diversion dam, about 1.9 mi upstream from the first streamflow-gaging station at site S1, water is diverted from the Arkansas River into a *sluiceway* channel that leads to the Fort Lyon Canal. About 0.5 and 1.1 canal miles upstream from the first streamflow-gaging station are a *wasteway* structure and a second diversion dam (canal mile 0.0) that can direct streamflow back to the Arkansas River. The remaining water in the canal is measured at site S1 with a 40-ft *Parshall flume* to determine compliance with the river priority system. No lands are irrigated directly from the Fort Lyon Canal upstream from site S1.

Table 1. Descriptions and summary of annual data for climatological stations near the Fort Lyon Canal

[Source: National Oceanic and Atmospheric Administration (1988–90); Colorado Climate Center (written commun., 1991). Site number indicates location of climatological station in figure 1. Elevation of station, in feet above sea level. Mean annual data is for the period of record indicated. --, no data]

Site number (fig. 1)	Climatological station name and index number[1]	County	Elevation	Annual total precipitation (inches)		Annual mean air temperature (degrees Fahrenheit)		Period of record		
				1989	1990	1989	1990	Years	Mean annual precipitation (inches)	Mean annual air temperature (degrees Fahrenheit)
W1	La Junta 4 NNE (4720)	Otero	4,200	8.27	17.40	53.4	53.8	1946–89	11.11	54.1
W2	Las Animas (4834)	Bent	3,890	10.73	16.87	53.7	54.0	1931–89	12.04	54.4
W3	John Martin (4388)	Bent	3,810	13.03	20.29	--	51.9	1941–89	11.92	54.1
W4	Lamar (4770)	Prowers	3,620	13.45	15.71	51.6	53.7	1931–89	14.41	53.8

[1]Index number is a unique identification number assigned when a climatological station is first established and is retained for that station indefinitely.

Direct-flow water rights permit diversions from the Arkansas River into the Fort Lyon Canal at a total rate of 933 ft^3/s. These diversions are distributed into the priorities listed in table 2. During a normal 8-month irrigation season (245 days), the three decreed flow rates, if delivered in full, would cover the irrigated land of the Fort Lyon Canal with a cumulative areal irrigation depth of about 0.87, 4.04, and 4.95 ft of water, assuming no conveyance losses. The actual delivery of each priority depends on the surface supplies available in the Arkansas River after all earlier dated (senior) water rights have been satisfied. Because sufficient flow generally is unavailable in the canal, the Fort Lyon Canal Company uses a rotation system to distribute water to about 400 shareholder laterals situated along the length of the canal. The shareholder laterals range in flow from about 0.54 to 84.0 ft^3/s (Fort Lyon Canal Company, written commun., 1990). During a change of canal ownership in about 1883, the sale of the canal system provided a perpetual water right of as much as 16 ft^3/s, which was free of canal company regulation, assessments, or charges, to several irrigation laterals located in the La Junta Division (Schuyler, 1910). This water agreement still exists in the present (1990) operation of the Fort Lyon Canal.

The Fort Lyon Canal is divided into five canal divisions (fig. 1) and delivers water to the divisions on a rotational basis. After water has been delivered for 48 hours to each of the shareholder laterals in a division, the water distribution is shifted to the next downstream division. When adequate surface water is available, more than one division can be served at the same time. A run of water has been completed when all five divisions have been supplied with delivery. During the 1989 irrigation season, there were 24 runs of water delivered to the five divisions of the Fort Lyon Canal and, during the 1990 irrigation season, there were 23 runs of water delivered (Fort Lyon Canal Company, written commun., 1990).

The streamflow-duration curve in figure 4 shows the percentage of time from March 1 to November 30 during 1989 and 1990 that various amounts of water were diverted by the Fort Lyon Canal. The first decree of 164.64 ft^3/s (table 2) was available in full more than 62 percent of the time, the second decree about 5 percent of the time, and the third decree less than 1 percent of the time during both years. About 30 percent of the time, the flow rate was between 100 and 165 ft^3/s, an amount that requires more than 30 days to complete a run of water to all shareholder laterals (Ron Callahan, Fort Lyon Canal Company, oral commun., 1991). The Fort Lyon Canal does not divert water about 8 percent of the time (fig. 4), which is due to approximately 15 days in early March and 15 days in late November when the Fort Lyon Canal is not operated because of participation in a winter water-storage program.

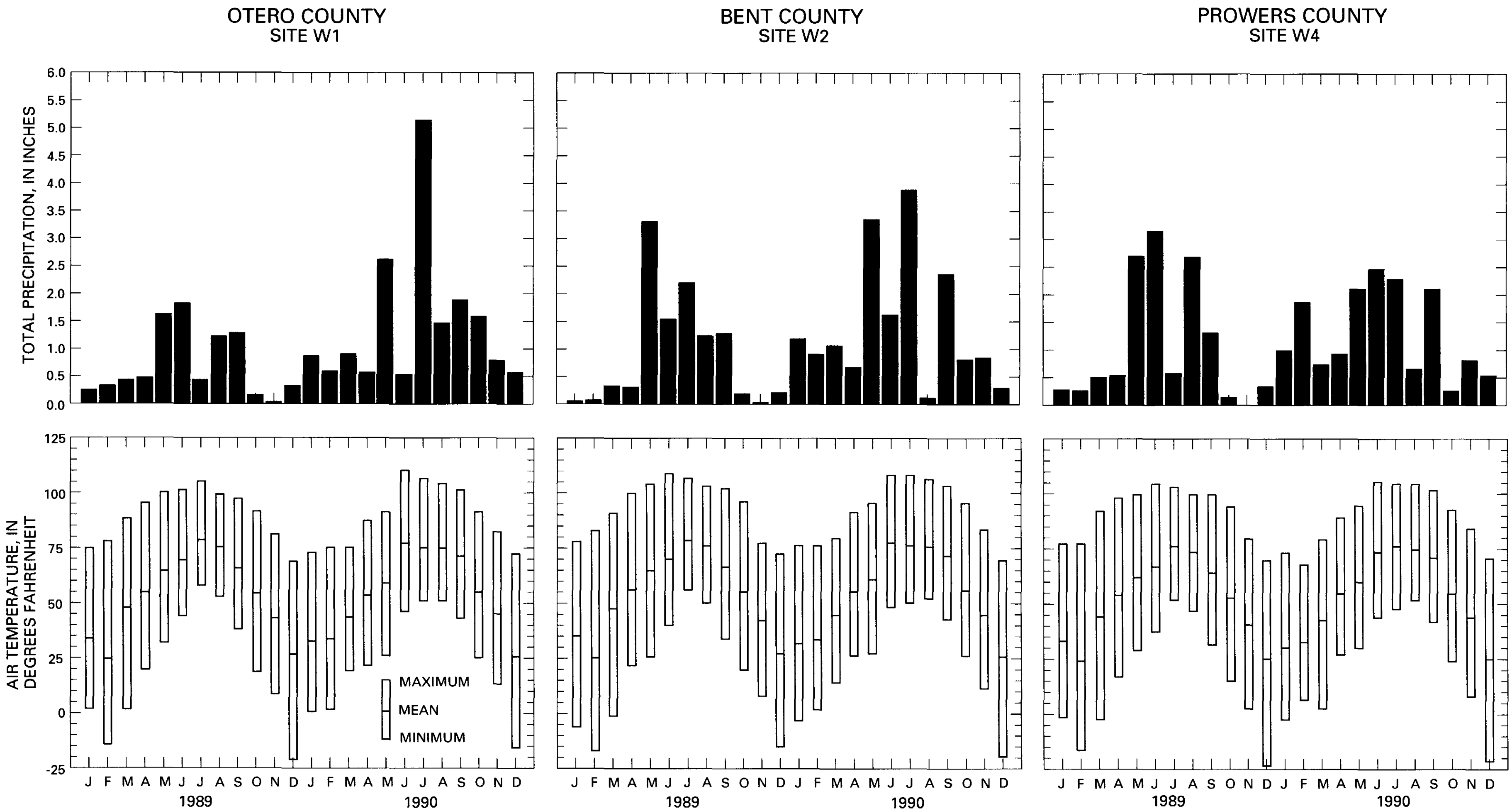


Figure 3. Monthly total precipitation and monthly maximum, mean, and minimum air temperature at climatological stations near the Fort Lyon Canal, 1989–90.

Table 2. Decreed priorities of the Fort Lyon Canal direct-flow system

[Source: Abbott (1985)]

Priority	Decreed flow (cubic feet per second)	Priority date
First	164.64	04–15–1884
Second	597.16	03–01–1887
Third	171.20	08–31–1893
TOTAL	933.00	

Water for the Great Plains Reservoir system (Abbott, 1985), which is owned and operated by the Amity Mutual Irrigation Company (Lamar, Colorado), is diverted from the Arkansas River into the Fort Lyon Canal. This water is transported about 46 mi in the Fort Lyon Canal to a bifurcation in the Las Animas Division where it is diverted into the Kicking Bird Canal (fig. 1). The Fort Lyon Canal direct-flow water-right priorities are senior to the Great Plains Reservoir system priority and are satisfied before any water is released into the Kicking Bird Canal. The Fort Lyon Canal Company, in exchange for diverting and transporting water for the Great Plains Reservoir system, has a preferential right to use and benefit from 5,483 *acre-ft* of water. The water can be stored in Queens Reservoir (fig. 1) until needed or stored in John Martin Reservoir for exchange with existing priorities.

The Fort Lyon storage system consists of the 45-mi-long Fort Lyon Storage Canal, two large off-stream storage reservoirs, Horse Creek Reservoir and Adobe Creek Reservoir, which are located several miles north of the study area (fig. 1), and Thurston Reservoir, a small, shallow lake located adjacent to the main canal (fig. 1). No attempt was made to measure diversions into or to measure the volume of water stored in any of the canal company reservoirs. The Fort Lyon Storage Canal delivers water from its headgate located on the north bank of the Arkansas River about 3 mi east of Manzanola to Horse Creek Reservoir and Adobe Creek Reservoir. The combined maximum storage capacity of the two off-stream reservoirs is about 131,440 acre-ft (Ruddy and Hitt, 1990). Horse Creek Reservoir delivers water in an unlined outlet canal directly to the Fort Lyon Canal, whereas releases from Adobe Creek Reservoir flow into the Adobe Creek Outlet Canal and then down the path of the natural channel of Adobe Creek into the Fort Lyon Canal. Thurston Reservoir, which is topographically lower than the Fort Lyon Canal, can pump collected irrigation water directly to the Fort Lyon Canal. All the storage reservoirs used in the operation of the Fort Lyon Canal are described in table 3 in their order of appearance along the main canal.

Acknowledgments

Personnel from the Fort Lyon Canal Company are acknowledged for their data-collection assistance during the study, and the personnel from the electrical utility companies that service the study area are acknowledged for supplying the power-consumption data. The cooperation and assistance from the many local residents in the study area who permitted access to their properties to collect water-use data were appreciated. Interviews with the farmers in the Arkansas River Valley and their familiarity with water-resources and agriculture practices provided invaluable insight into the art of irrigation in a semiarid environment. In addition, the assistance offered by the Office of the Colorado State Engineer in providing hydrologic data and the compilation of extensive agricultural data by personnel of the U.S. Agricultural Stabilization and Conservation Service offices located in Otero, Bent, and Prowers Counties are acknowledged. The diligent field initiative and extra-long working days volunteered to complete the job by Michael J. Haley of the U.S. Geological Survey were greatly appreciated.

SURFACE-WATER WITHDRAWALS

Surface-water withdrawals in the five Fort Lyon Canal divisions were determined using data from seven streamflow-gaging stations (sites S1–S7) shown in figure 1 and listed in table 4. Data collection at all the streamflow-gaging stations began during 1988. Five of the seven streamflow-gaging stations were located at division boundaries to account for flow in each canal division. Two additional streamflow-gaging stations were located on Adobe Creek (site S3) and the Wheatridge Lateral (site S7) to account for the major inflow and outflow, except for the shareholder laterals, to the Fort Lyon Canal during the 2 years of the study.

A wasteway located near the end of the study area (site S8) (fig. 1) was established as a temporary streamflow-gaging station in 1989 to record water discharged from the end of the Wheatridge Lateral to the Amity Canal. Data collected from this station indicated that the frequency and relative magnitude of water spilling to the Amity Canal were small during the study period; however, a large amount of mobile debris at the location prevented accurate discharge measurements during several observed flow periods, and a

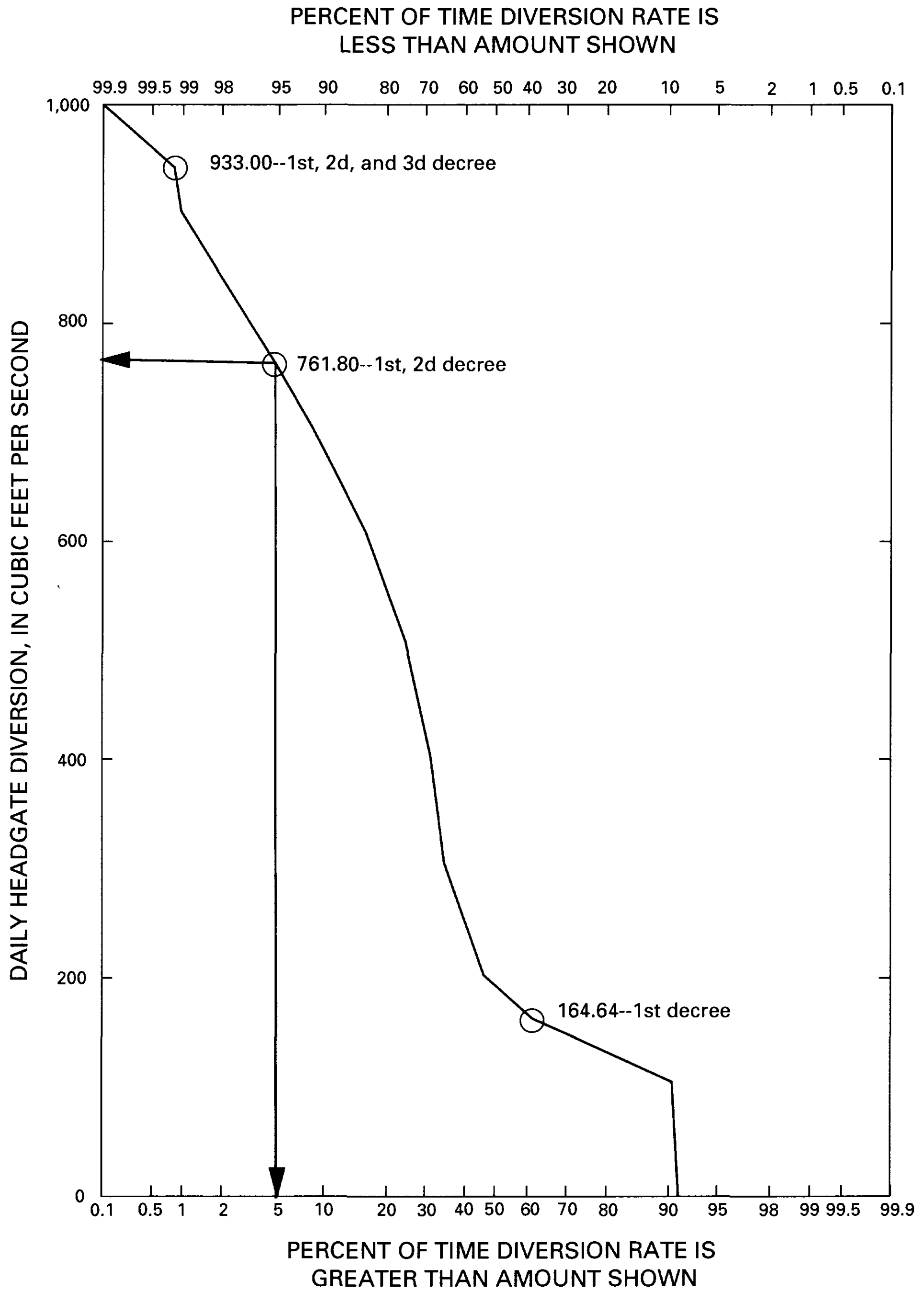


Figure 4. Streamflow-duration curve for the streamflow-gaging station 07122005, Fort Lyon Canal near La Junta (site S1), March through November, 1989–90. Five percent of the time, the daily headgate diversion equals or exceeds the first and second decree of 761.80 cubic feet per second.

Table 3. Reservoirs owned or used in the irrigation deliveries supplied by the Fort Lyon Canal Company

[Sources: Abbott (1985); Ruddy and Hitt (1990); Fort Lyon Canal Company (written commun., 1991). Local name identifies the reservoir to residents of the study area]

Reservoir name (fig. 1)	Local name	Canal location[1] (canal miles)	Sources and conveyance of water	Year reservoir completed	Storage capacity (acre-feet)		Withdrawals (acre-feet)	
					Decree	Maximum	1989	1990
Horse Creek	Timber Lake	16.6	Arkansas River Fort Lyon Storage Horse Creek Outlet Horse Creek	1971	28,000	43,120	0	0
Adobe Creek	Blue Lake	22.7	Arkansas River Fort Lyon Storage Adobe Creek Outlet Adobe Creek	1969	87,000	88,320	48,670	31,410
Queens	Nee Skah	95.6	Arkansas River Fort Lyon Canal Kicking Bird Canal	1896	5,483	32,690	434	0
Thurston	Thurston Lake	95.7	Arkansas River Fort Lyon Canal	1928	1,515	8,260	140	110

[1]Canal location is referenced from the second diversion dam on the Fort Lyon Canal (see fig. 1) to the location of the reservoir inflow on the Fort Lyon Canal.

stage-discharge rating was not prepared. Review of the partial gage-height record collected at this location from a continuous water-stage recorder, combined with on-site observations during several flow periods, indicated that water loss from the study area at this waste-way location was small.

The following discussion of each division of the Fort Lyon Canal begins with a brief description of the data-collection locations and methods, followed by the 1989 and 1990 surface-water withdrawals. Each withdrawal is calculated from the difference between the amount of water entering the division (inflow) and the amount of water leaving the division (outflow). The difference in these two quantities include the shareholder withdrawals in the division and include the conveyance losses in the Fort Lyon Canal during the month. Inflows to the Fort Lyon Canal from the storage reservoirs listed in table 3 are discussed as part of the appropriate canal division.

Division 1—La Junta

The La Junta Division of the Fort Lyon Canal extends from canal mile 1.1 (site S1) to canal mile 7.1 (site S2) (table 4) and averages about 2,150 irrigated acres. Diversion of surface water from the Arkansas River into the Fort Lyon Canal is measured by a concrete 40-ft Parshall flume (site S1), hereafter called the headgate. Discharge as determined from the flume rating was accurate within 6 percent of measured discharge during freeflow conditions in the flume but was only accurate within 40 percent of measured discharge during many periods of backwater (submergence). The canal was subject to frequent scour-fill episodes of sand movement upstream and downstream from the flume that created a changing control condition at the headgate location. However, sand deposition was not observed in the flume cross section during either year of the study.

Since the flume rating was inaccurate during many periods of backwater, adjustments were made to increase the record of headgate flow volume whenever the discharge was greater downstream at site S2 than at the headgate (site S1). Since there are no inflows or large diversions of water, except for 20 regulated shareholder laterals, in this 6-mi reach of the Fort Lyon Canal, discharge at the headgate was estimated using discharge at site S2, without consideration of conveyance losses. Adjustments to increase the discharge at the headgate generally were required only when flow exceeded about 300 ft^3/s, which occurred most often during summer when water stage in the flume was greater than 1.7 ft. Water stage reached a maximum depth of 4.5 ft in the flume during the study.

Table 4. Summary of information for streamflow-gaging stations on or near the Fort Lyon Canal

[Local name identifies the location to residents of the study area. ft³/s, cubic feet per second; mo, month; d, day; yr, year]

Site number (fig. 1)	U.S. Geological Survey station name and number	Local name	Division	Canal location[1] (canal mile)	Period of record[2] (mo/yr)	Daily discharge	
						Maximum measured (ft^3/s)	Date (mo/d/yr)
S1	Fort Lyon Canal near La Junta 07122005	Headgate	La Junta	1.1	07/88–11/90	959	07/14/89 07/31/90
S2	Fort Lyon Canal near Casa 07122060	Keesee Bridge	Horse Creek	7.1	05/88–11/90	927	07/08/90
S3	Adobe Creek near Fort Lyon Canal 381024103195401	Blue Lake spillway	Horse Creek	[3]22.7	05/88–11/90	398	07/18–20/89 08/27–29/90
S4	Fort Lyon Canal near Cornelia 07122105	77-check	Las Animas	28.7	05/88–11/90	847	07/09/90
S5	Fort Lyon Canal near Hasty 07122200	Hasty Road	Limestone	50.7	05/88–11/90	634	07/25/90
S6	Fort Lyon Canal near Big Bend 07122350	Near Wollert check	Lamar	76.9	05/88–11/90	548	07/19/89
S7	Wheatridge Lateral near May Valley 07122385	Wheatridge Lateral	Lamar	103.7	08/88–11/90	191	06/08/89

[1]Canal location is referenced from the second diversion dam on the Fort Lyon Canal (see fig. 1).

[2]Length of available discharge record from which flow characteristics were used to determine station rating; discharge records may exist for other time periods.

[3]Canal mile is for location of reservoir inflow to the Fort Lyon Canal and does not indicate the actual location of the streamflow gage.

Monthly surface-water inflow to, surface-water outflow from, and total irrigation withdrawals in the La Junta Division are shown in *A* in figure 5. Canal inflow to the division during the irrigation year at site S1 totaled about 161,900 acre-ft in 1989 and 170,500 acre-ft in 1990. Large quantities of irrigation water were transported through the division each month, and the canal inflow to the division ranged from 5,130 acre-ft in March 1990 to 39,090 acre-ft in June 1990 (*A* in fig. 5).

The total annual surface-water withdrawals in the La Junta Division were 12,700 acre-ft (about 7.8 percent of the division inflow) in 1989 and 11,100 acre-ft (about 6.5 percent of the division inflow) in 1990. During the irrigation season, monthly surface-water withdrawals in the division ranged from 300 acre-ft during April 1989 to 4,010 acre-ft in July 1989 (*A* in fig. 5). Surface-water withdrawals were small in March and April, increased sharply in May and June, peaked during July, and decreased gradually from August through November during both years. The general trend is that surface-water withdrawals increase when larger quantities of water are transported in the Fort Lyon Canal. This increase is a combination of increased conveyance losses from the Fort Lyon Canal and of increased shareholder withdrawals taken for beneficial crop use.

The crop demand for water is difficult to satisfy with equivalent monthly delivery of water in this large irrigation system. The combined surface-water withdrawals during June and July of about 5,000 acre-ft is similar during both irrigation years, whereas the monthly distribution is different (*A* in fig. 5). During June and July of 1989, the inflow at site S1 was about the same. The scheduled time for the La Junta Division to receive water during the delivery rotation by the Fort Lyon Canal Company is indicated by the large withdrawal in July 1989 that follows the small withdrawal during June (*A* in fig. 5). During a run of water, the timing of division withdrawals in the rotation schedule has

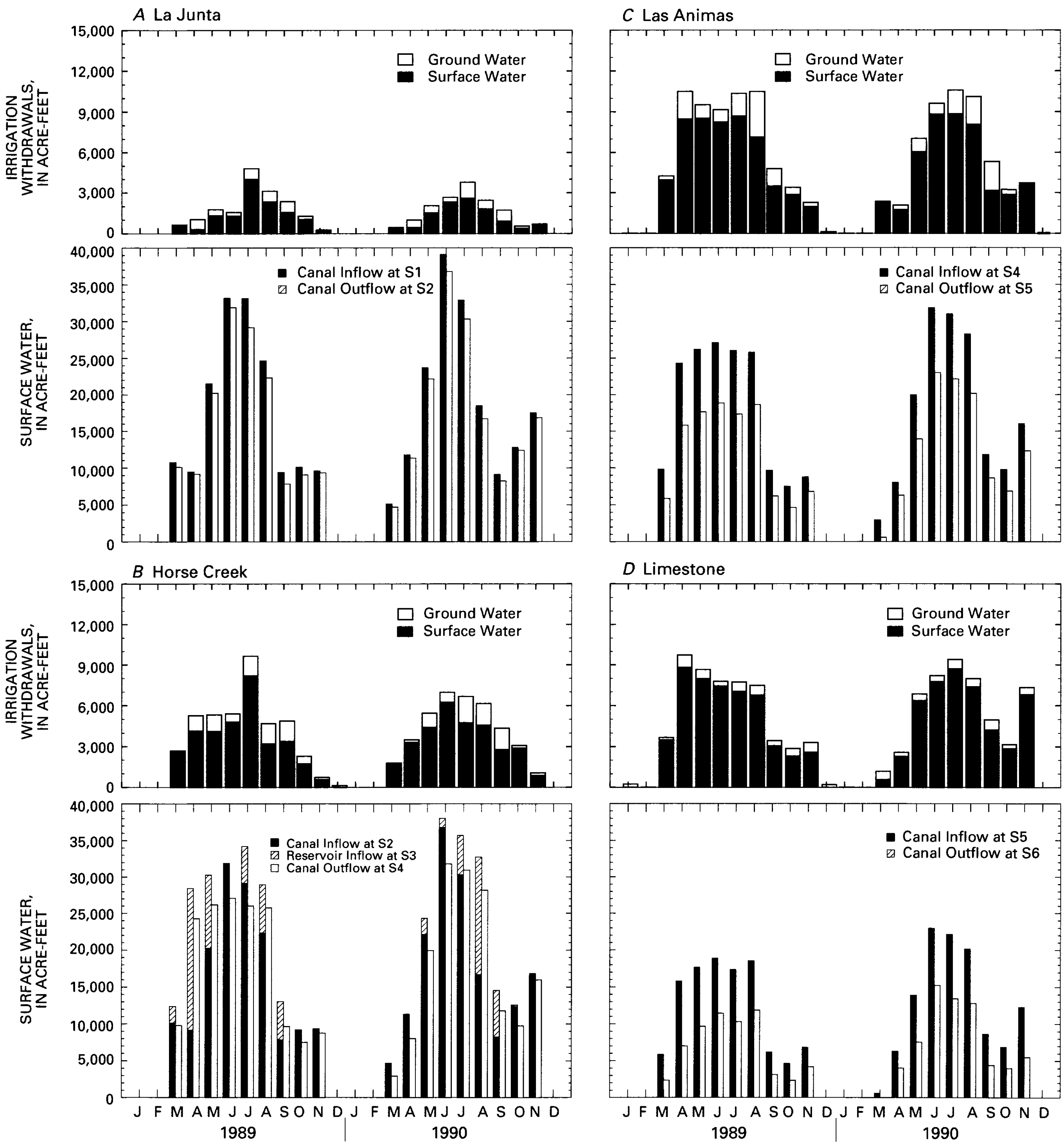


Figure 5. Monthly surface-water inflow, outflow, and total irrigation withdrawals of the Fort Lyon Canal, by canal division (*A*, La Junta; *B*, Horse Creek; *C*, Las Animas; *D*, Limestone; and *E*, Lamar), 1989–90. Irrigation season is from March 15 through November 15, which generally corresponds to the period of operation of the main canal.

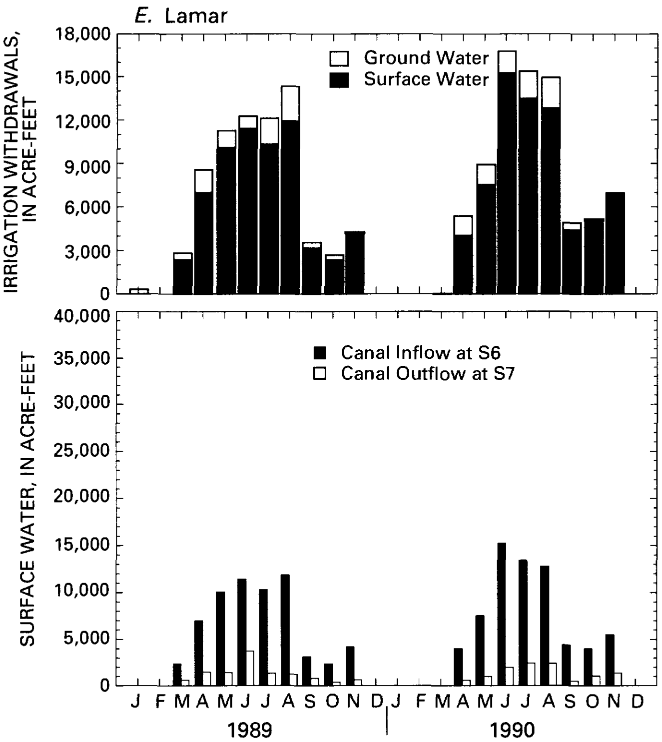


Figure 5. Monthly surface-water inflow, outflow, and total irrigation withdrawals of the Fort Lyon Canal, by canal division (*A*, La Junta; *B*, Horse Creek; *C*, Las Animas; *D*, Limestone; and *E*, Lamar), 1989–90. Irrigation season is from March 15 through November 15, which generally corresponds to the period of operation of the main canal--Continued.

the effect of shifting the month of maximum withdrawals backward to June or forward to August, in many years. The more uniform distribution of monthly withdrawals during 1990 is better suited for growing crops that have negligible drought tolerance and for meeting the critical stages of growth that exists for the variety of crops irrigated from the Fort Lyon Canal.

Division 2—Horse Creek

The Horse Creek Division of the Fort Lyon Canal extends from canal mile 7.1 (site S2) to canal mile 28.7 (site S4) (table 4) and averages about 9,380 irrigated acres. The Fort Lyon Canal can receive inflow of supplemental storage water in the division from the off-stream reservoirs of Horse Creek and Adobe Creek (table 3). A concrete 20-ft Parshall flume (site S3) is located on Adobe Creek about 3 mi upstream from the Adobe Creek confluence with the Fort Lyon Canal (fig. 1). Daily discharge was determined at a non-recording gaging station at site S3 that was read twice daily for water-stage height. The flume rating at site S3 was calibrated using discharge measurements compiled from nine controlled flow releases from Adobe Creek Reservoir that ranged from 12 to 385 ft^3/s during 1989–90. Horse Creek Reservoir was not used during the study period; therefore, no flow measurements were made from this storage source.

Monthly surface-water inflow to, surface-water outflow from, and total irrigation withdrawals in the Horse Creek Division are shown in *B* in figure 5. Combined inflow to the division from the La Junta Division (site S2) and Adobe Creek Reservoir (site S3) during the irrigation year totaled about 197,870 acre-ft in 1989 and 190,810 acre-ft in 1990. Canal inflow from the La Junta Division ranged from 4,700 acre-ft in March 1990 to 36,770 acre-ft in June 1990 (*B* in fig. 5).

Long reaches of the Horse Creek Division frequently receive water at the same time as the La Junta Division because of the availability of an adequate supply of water in the Fort Lyon Canal. Therefore, the general trend of monthly surface-water flows and surface-water withdrawals is similar to the trend in the La Junta Division (*A* and *B* in fig. 5). However, the monthly surface-water withdrawals are substantially larger in the Horse Creek Division because of the greater irrigated acreage.

During 1989, storage water released from Adobe Creek Reservoir contributed 48,670 acre-ft (table 3), or about 25 percent, of the total surface-water inflow to the Horse Creek Division. In 1990, the contribution was decreased to 31,410 acre-ft (table 3), or about 16 percent of the total surface-water inflow. Maximum inflow from Adobe Creek Reservoir occurred during April 1989 and August 1990 (*B* in fig. 5), indicating the benefits of this supplemental source for meeting the irrigation requirements of crops during months of generally low streamflow in the Arkansas River. The primary asset of this supplemental irrigation supply to the Fort Lyon Canal is indicated by the frequency of use. During 13 of the 16 months (the first 15 days in March and the last 15 days in November are excluded during each year) of the 1989 and 1990 irrigation seasons (table 9), and during most of the large consumptive-use months, the reservoir provided some extra water needed to meet the crop irrigation demand in the study area.

The total annual surface-water withdrawals in the Horse Creek Division were 32,770 acre-ft (about 16.6 percent of the division inflow) in 1989 and 31,410 acre-ft (about 16.5 percent of the division inflow) in 1990. During the irrigation season, monthly surface-water withdrawals in the division ranged from 580 acre-ft during November 1989 to 8,200 acre-ft in July 1989 (*B* in fig. 5). Withdrawals began in March, increased steadily through the middle of the irrigation season, and then generally decreased through November of both years. Although surface water was available in November for crop irrigation, only a small amount was withdrawn in the division during either year of the study, which indicates that the crop irrigation requirement in the Horse Creek Division decreases rapidly near the end of the irrigation season.

Division 3—Las Animas

The Las Animas Division of the Fort Lyon Canal extends from canal mile 28.7 (site S4) to canal mile 50.7 (site S5) (table 4) and averages about 13,900 irrigated acres. Water for the Great Plains Reservoir system is diverted from the Fort Lyon Canal into the Kicking Bird Canal at canal mile 45.7 (fig. 1). However, during the 1989–90 study period, no water was diverted from the Fort Lyon Canal for delivery to the Great Plains Reservoir system.

Monthly surface-water inflow to, surface-water outflow from, and total irrigation withdrawals in the Las Animas Division are shown in *C* in figure 5. Canal inflow to the division during the irrigation year totaled about 165,100 acre-ft in 1989 and 159,400 acre-ft in 1990. Large quantities of irrigation water were transported through the division each month, and the canal inflow to the division ranged from 2,940 acre-ft in March 1990 to 31,810 acre-ft in June 1990 (*C* in fig. 5). During 1990, the trend of monthly surface-water inflow and surface-water withdrawals is similar to the trend for the La Junta and Horse Creek Divisions (*A*, *B*, and *C* in fig. 5). The monthly withdrawals are larger in the Las Animas Division than in the two upstream divisions because of the greater irrigated acreage in the division.

The total annual surface-water withdrawals in the Las Animas Division were 53,400 acre-ft (about 32.3 percent of the division inflow) in 1989 and 45,600 acre-ft (about 28.6 percent of the division inflow) in 1990. During the irrigation season, monthly surface-water withdrawals in the division ranged from 1,740 acre-ft during April 1990 to 8,850 acre-ft in July 1990 (*C* in fig. 5). The withdrawals were small early in the irrigation season and, except for April and May 1989, increased steadily through July, and then decreased through the end of the irrigation season, except for November 1990. During April and May 1989, the large withdrawals were needed to replace soil moisture lost during an extended dry period that included the Las Animas Division and the two more eastern divisions of the study area. At site W2, for more than 7 months, from October 1, 1988, to May 14, 1989, there were only 5 days that had daily precipitation greater than 0.10 in., 2 days that had precipitation greater than 0.20 in., and no days that had precipitation greater than 0.30 in. (National Oceanic and Atmospheric Administration, 1988–90). The larger withdrawals during November 1990 are taken to ensure that adequate soil moisture is available in the alfalfa fields for the dry months of winter that are common in the area.

Division 4—Limestone

The Limestone Division of the Fort Lyon Canal extends from canal mile 50.7 (site S5) to canal mile 76.9 (site S6) (table 4) and averages about 29,660 irrigated acres. Monthly surface-water inflow to, surface-water outflow from, and total irrigation withdrawals in the Limestone Division are shown in *D* in figure 5. Canal inflow to the division for the irrigation year totaled about 111,700 acre-ft in 1989 and 113,800 acre-ft in 1990. Canal inflow to the division during the irrigation season ranged from 580 acre-ft in March 1990 to 22,980 acre-ft in June 1990 (*D* in fig. 5).

The total annual surface-water withdrawals in the Limestone Division were 49,400 acre-ft (about 44.2 percent of the division inflow) in 1989 and 46,880 acre-ft (about 41.2 percent of the division inflow) in 1990. During the irrigation season, monthly surface-water withdrawals in the division ranged from 580 acre-ft during March 1990 to 8,800 acre-ft in April 1989 (*D* in fig. 5). The small surface-water withdrawal of 580 acre-ft in March 1990 resulted from construction delays at the beginning of the Fort Lyon Canal system that resulted in an operational delay in diverting water from the Arkansas River, which slowed the arrival of water to the Limestone Division. The large irrigation withdrawal that occurred in the division during November 1990 was taken to ensure that adequate soil moisture was available during the winter months for the extensive acres of alfalfa in the division.

The trend of monthly surface-water flows and surface-water withdrawals in the Limestone Division is similar to the trend for the upstream divisions during 1990, but, except for the Las Animas Division, the withdrawals were dramatically different during 1989 (fig. 5). The surface-water withdrawals during 1989 were largest in April, steadily decreased from May through August, and then sharply decreased in September and October. During April 1989, the large withdrawals replaced soil moisture lost during an extended dry period in the division. At site W4, for more than 7 months, from October 1, 1988, to May 8, 1989, there were only 5 days that had daily precipitation greater than 0.10 in., 2 days that had precipitation greater than 0.30 in., and no days that had precipitation greater than 0.50 in. (National Oceanic and Atmospheric Administration, 1988–90).

Division 5—Lamar

The Lamar Division of the Fort Lyon Canal extends from canal mile 76.9 (site S6) to canal mile 103.7 (site S7) (table 4) and averages about 36,540 irrigated acres. Although site S7 is the end of the Fort Lyon Canal, water that is delivered past this site is used to irrigate acreage in the Lamar Division (fig. 1). The Fort Lyon Canal can receive inflow of supplemental storage water from Queens Reservoir and Thurston Reservoir (table 3) in the Lamar Division. Located at canal mile 101.8 is an ungaged inlet for a control basin (fig. 1). The control basin is used to protect the canal by regulating the flow of water near the end of the Fort Lyon Canal. Water that enters the control basin eventually is released at canal mile 103.6 through an ungaged channel that enters the Fort Lyon Canal upstream from site S7. A standard concrete 10-ft Parshall flume is located at canal mile 103.7 (site S7) to measure water entering the Wheatridge Lateral, the last shareholder lateral of the Fort Lyon Canal.

During the irrigation season, 140 acre-ft of surface water was withdrawn from Thurston Reservoir in 1989, and 110 acre-ft of canal inflow was withdrawn in 1990 (table 3). These volumes were added to the monthly withdrawals for the Lamar Division shown in *E* in figure 5. These volumes of water were estimated, using a steady yield of 4.5 ft^3/s (about 2,000 gal/min) in June 1990, which was measured at Thurston Reservoir after 6 hours of normal pump operation, and using a Fort Lyon Canal Company record (Janet Miller, written commun., 1990) of the hours of pump operation time. In 1990, before the start of the irrigation season, the Fort Lyon Canal Company modified the conveyance system for withdrawals from the reservoir to the Fort Lyon Canal, which may have changed the pump-discharge rate that existed before the modified conveyance system was installed. After discussions with personnel of the Fort Lyon Canal Company and because of the small annual inflow to the Fort Lyon Canal from this storage source, no adjustment was made to the 1989 withdrawal from Thurston Reservoir to account for a difference in pump-discharge rate. The Fort Lyon Canal Company (Janet Miller, written commun., 1989) reported that an additional 434 acre-ft of surface-water inflow to the Fort Lyon Canal was withdrawn from Queens Reservoir (table 3) during May 1989. This volume was added to the total monthly withdrawal for May 1989 in the Lamar Division.

Monthly surface-water inflow to, surface-water outflow from, and total irrigation withdrawals in the Lamar Division are shown in *E* in figure 5. Combined inflow to the division during the irrigation year totaled about 62,880 acre-ft in 1989 and 67,010 acre-ft in 1990. Canal inflow from the Limestone Division during the irrigation season ranged from no flow in March 1990 to 15,250 acre-ft in June 1990 (*E* in fig. 5). As indicated in the first paragraph of this section, deliveries beyond site S7 are used to irrigate acreage in the Lamar Division; therefore, that quantity of water, shown as surface-water outflow at the bottom of *E* in figure 5, has been added to each of the monthly surface-water withdrawals at the top of *E* in figure 5.

The trend of monthly surface-water inflow and surface-water withdrawals is similar to the trend in the upstream divisions (fig. 5). The inflow to the Lamar Division was small in March, increased steadily through June, and then dramatically decreased after August. The absence of any withdrawal in March 1990 to the Lamar Division was caused by an operational delay in diverting water from the Arkansas River because of construction delays at the beginning of the Fort Lyon Canal system. Because of the decrease in irrigation withdrawals in the upstream divisions during November 1990, there was adequate water withdrawn to recharge the soil moisture of the extensive field acreage used to grow alfalfa in the Lamar Division.

Total Surface-Water Withdrawals

The total surface-water inflow diverted from the Arkansas River (81 percent of surface-water withdrawals) and released from reservoir storage (19 percent of surface-water withdrawals) to the Fort Lyon Canal during the study period was 211,150 acre-ft (about 2.3 acre-ft/acre) in 1989 and 202,000 acre-ft (about 2.2 acre-ft/acre) in 1990 (table 5). Total surface-water withdrawals for the Fort Lyon Canal decreased about 5 percent between 1989 and 1990, whereas the irrigated acreage increased about 0.1 percent. Although the irrigated acreage changed less than 2 percent in any canal division during the study, the average surface-water withdrawal decreased in the first four divisions of the canal between about 4 and 15 percent, whereas surface-water withdrawal in the Lamar Division increased by about 7 percent during 1990. Surface-water withdrawals constituted about 85 percent of the total irrigation withdrawals supplied to the five divisions of the Fort Lyon Canal system during the 2 years of the study.

Table 5. Summary of annual surface-water withdrawals and surface-water irrigated cropland of the Fort Lyon Canal, by canal division, 1989–90

Division	Total surface-water withdrawals (acre-feet)		Surface-water irrigated cropland (acres)		Average surface-water withdrawals (acre-feet per acre)	
	1989	1990	1989	1990	1989	1990
La Junta	12,700	11,100	2,160	2,140	5.9	5.2
Horse Creek	32,770	31,410	9,460	9,290	3.5	3.4
Las Animas	53,400	45,600	13,840	13,960	3.9	3.3
Limestone	49,400	46,880	29,420	29,900	1.7	1.6
Lamar	62,880	67,010	36,700	36,380	1.7	1.8
FORT LYON CANAL	211,150	202,000	91,580	91,670	[1]2.3	[1]2.2

[1]Represents an area-weighted average of the five canal divisions.

Total surface-water withdrawals generally increased from the La Junta to the Lamar Divisions as the total irrigated acreage increased (table 5). The average withdrawal per acre generally decreased from the La Junta to the Lamar Divisions (table 5), indicating the cumulative effects of conveyance loss in the Fort Lyon Canal and greater irrigated acreage in each successive downstream division. The average withdrawal of more than 5 acre-ft/acre in the La Junta Division indicates that conveyance loss is an important component of surface-water withdrawals in the first 6 mi of the Fort Lyon Canal. About 100 percent more water per acre is withdrawn in the Horse Creek and the Las Animas Divisions than in the Limestone and the Lamar Divisions. The additional 0.6 acre-ft/acre surface-water withdrawal in the Las Animas Division during 1989 was primarily the result of the large withdrawals that occurred in April and May of that year (*C* in fig 5). Supplemental water supplies are needed to meet crop consumptive use, because less than 2 acre-ft/acre of surface water was withdrawn in the Limestone Division or was available for withdrawal in the Lamar Division during 1989 and 1990 (table 5). Natural subirrigation of crops in the Limestone and Lamar Divisions is combined with the use of water from tail-water pits in the Las Animas, Limestone, and Lamar Divisions and provides an additional source of water to supplement irrigation supplies in these large acreage divisions of the Fort Lyon Canal. Subirrigation occurs naturally in the two eastern divisions of the study area where ground water from a raised water table is within the root zone and is available for crop consumptive use. Tail-water pits are designed to collect and store excess runoff water from irrigated fields. When needed, the collected water is redistributed back onto the fields, generally using electrical pumps.

CONVEYANCE LOSSES

Conveyance losses in this report consist of *seepage*, evaporation, incidental transpiration by vegetation along the banks of the Fort Lyon Canal, and operational waste losses. Because evaporation from the canal surface is usually negligible when compared to seepage losses in unlined canals (Rohwer and Stout, 1948) and substantial losses due to transpiration by vegetation are assumed to be negligible because of an aggressive maintenance program by canal company personnel to remove brush and trees, in or along the banks of the Fort Lyon Canal, the evapotranspiration losses are included in the conveyance-loss estimate. Operational-waste losses occur during the delivery of water by sluicing, gate leakage, and by spills from flooding and during physical breaks in the canal banks. Operational-waste information was difficult to obtain and quantify and, therefore, is included in the conveyance-loss estimate of a canal division. All conveyance losses occurring in lateral diversions and farm-distribution systems are excluded from the analysis and were beyond the scope of the study to determine.

Conveyance losses in the Fort Lyon Canal were determined by totaling the volume of inflow and outflow in each canal division as surface water moved through the canal to a downstream area of intended use. Time-of-travel measurements were made for about 77 mi of the Fort Lyon Canal, in reaches that ranged from 3 to 15 mi in length. These data were used to develop a relation between traveltime and discharge in each of the first four divisions of the canal so that the passage time for a run of water could be predicted. Conveyance losses were computed in 24-hour intervals when there were no withdrawals in the division and when the daily mean discharge at the upstream gaging station in the division varied less than 10 percent from the daily mean discharge of the previous day. Information to determine irrigation withdrawals at shareholder laterals was available only during the 1990 irrigation year (Janet Miller, Fort Lyon Canal Company, oral commun., 1991); therefore, the 1989 irrigation year is excluded from the conveyance-loss analysis. Conveyance losses for the Lamar Division were not estimated using the daily discharge data, because adequate information to develop the relation between traveltime and discharge was not collected in the last division of the canal.

If the maximum error in the gaging-station records is assumed to be ±10 percent, the small difference between many of the estimates of daily conveyance loss do not directly substantiate the hypothesis that water is lost from the Fort Lyon Canal through seepage. Except for the large losses in the La Junta Division (where only flows less than 300 ft^3/s were considered), the potential error range for a division is sufficient by itself to account for the computed difference in many of the daily flow volumes without including any additional physical phenomena. However, all of the computations of daily flow determined in the La Junta, Horse Creek, and Las Animas Divisions during 1990 indicated that irrigation water was lost, signifying that a true loss does exist in each of these divisions.

Daily conveyance losses in the Fort Lyon Canal were computed for three flow seasons. April and May were designated as spring because of the low-flow conditions that exist in the Fort Lyon Canal during the early months of irrigation when the crops are young and air temperatures are cool in the study area. June through August were designated as summer when flow conditions in the Fort Lyon Canal are large enough to satisfy a large irrigation demand that results from actively growing crops and high air temperatures in the area. September through mid-November were designated as fall because of the decrease in irrigation as the crops mature and cool air temperatures return to the area. Statistical analysis, using the Kruskal-Wallis nonparametric test (Minitab, Inc., 1989), indicated that a significant difference ($p = 0.05$), at the 95-percent confidence level, existed in the rate of daily conveyance losses between the three seasons. March was excluded from the seasonal analysis because only a few daily conveyance-loss measurements were available at the beginning of the irrigation season.

Statistical analysis, using regression methods, indicated that daily conveyance-loss data were significantly related to canal discharge and to water stage in the canal. However, regression analyses accounted for less than 50 percent of the variation that was observed in the conveyance losses. Because no definitive statistical relation existed between the daily conveyance-loss data and canal discharge or water stage, the conveyance losses were not quantified on a monthly or an annual basis. The discussion of conveyance losses in this report is limited to a presentation of the range of estimates that were determined from existing daily conveyance-loss data for each canal division. Daily conveyance-loss information for the four upstream canal divisions is summarized for each season using boxplots.

A boxplot (fig. 6) is a useful tool for examining the central tendency and distribution of a conveyance-loss data set. The median shows the center location of the data distribution. The spread of the data (the central 50 percent) is called the interquartile range (IQR) and is the length of the box. The lengths of the lines (whiskers) relative to the box indicate how stretched the tails of the distribution are, and the lines extend to the farthest data value within 1.5 times the IQR length. Outliers between 1.5 to 3.0 times the IQR are shown as "*", and farout data values greater than 3.0 times the IQR are shown as "•". The width of the box has no particular meaning. Further information on boxplots is contained in Tukey (1977).

Division 1—La Junta

Because flow adjustments that were based on hydrographic comparison were used at the headgate station when the flow exceeded about 300 ft^3/s, the discussion of conveyance losses in the La Junta Division is limited to periods when flow in the Fort Lyon Canal was less than 300 ft^3/s. The flow-duration curve for the Fort Lyon Canal headgate (fig. 4) indicates that about 57 percent of the time (65 percent minus 8 percent non-operation time), the flow was less than 300 ft^3/s during the 2 study years.

The actual rate of conveyance loss in the La Junta Division on any given day also could be smaller than the computed values for 1990, as much as 32 acre-ft/d smaller, because of several unregulated irrigation laterals near the upper end of the division. Field observations during the study indicated that these laterals generally withdrew less than the maximum-allowed flow and were used more frequently during the summer. These diversions from the Fort Lyon Canal were not controlled by the canal company and, for the purposes of establishing an upper bound estimate of the conveyance loss, were assumed to have zero withdrawal throughout 1990. This correction is not needed for the other downstream canal divisions.

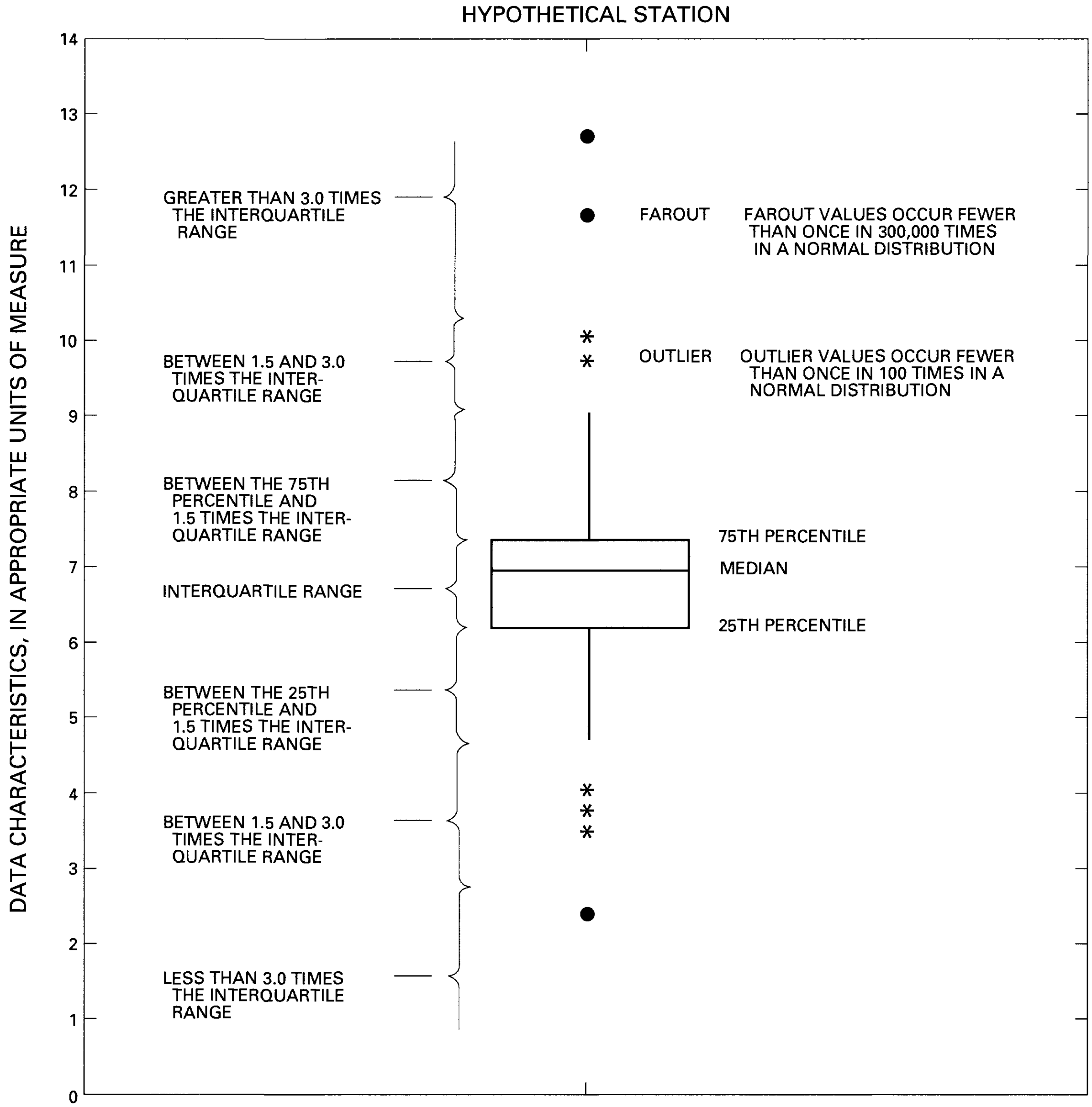


Figure 6. Explanation of information shown on a boxplot.

Daily rates of conveyance losses for the 6 canal miles in the La Junta Division are summarized for 1990 in *A* in figure 7. Except for the few outliers, the data indicate that daily conveyance losses for flows less than 300 ft^3/s during spring ranged from 12 to 270 acre-ft/d; during summer ranged from 138 to 276 acre-ft/d; and during fall ranged from 132 to 246 acre-ft/d. The data indicate that the median conveyance loss for flows less than 300 ft^3/s during the three seasons is about 84,228, and 180 acre-ft/d. The largest conveyance loss measured during 1990 in the La Junta Division was during summer and was about 432 acre-ft/d.

Daily rates of conveyance losses expressed in acre-feet per day per mile in the La Junta Division are summarized for 1990 in *B* in figure 7. The data indicate that, except for outliers, daily conveyance losses per mile for flows less than 300 ft^3/s during spring ranged from 2 to 45 (acre-ft/d)/mi; during summer ranged from 23 to 46 (acre-ft/d)/mi; and during fall ranged from 22 to 41 (acre-ft/d)/mi in the La Junta Division. The data indicate that the median convey-

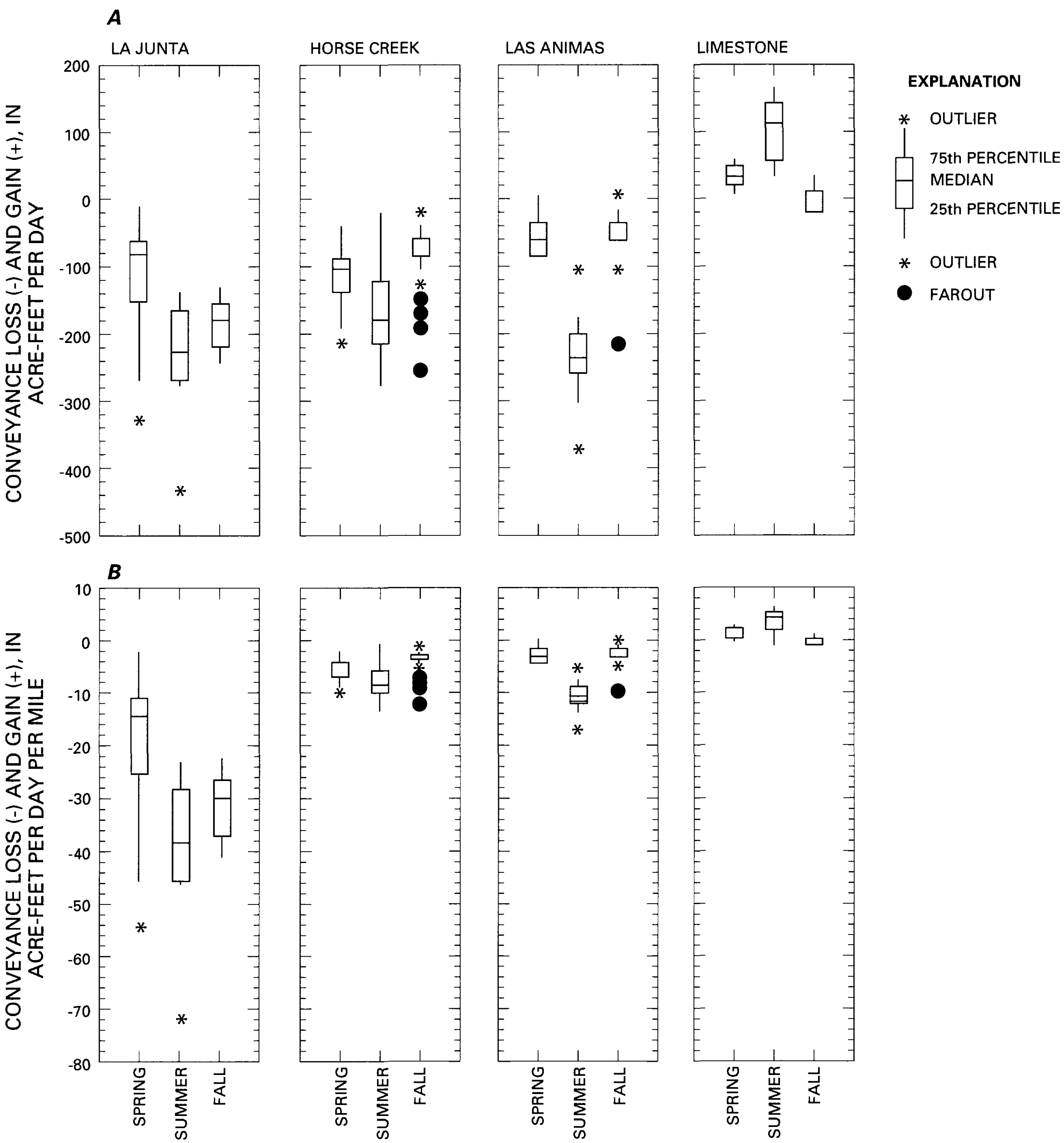


Figure 7. Boxplots of conveyance-loss rates (*A*, in acre-feet per day and *B*, in acre-feet per day per mile) during three seasons for four divisions of the Fort Lyon Canal, 1990. Spring is April and May, summer is June through August, and fall is September through mid-November.

ance loss for flows less than 300 ft^3/s during the three seasons is about 14, 38, and 30 (acre-ft/d)/mi. The largest conveyance loss measured during 1990 in the La Junta Division was during summer and was about 72 (acre-ft/d)/mi.

Division 2—Horse Creek

Daily rates of conveyance losses for the 21.6 canal miles in the Horse Creek Division are summarized for 1990 in *A* in figure 7. Except for outliers, the data indicate that daily conveyance losses during spring ranged from 43 to 194 acre-ft/d; during summer ranged from 22 to 281 acre-ft/d; and during fall ranged from 43 to 108 acre-ft/d in the division. The data also indicate that the median conveyance loss during the three seasons is about 108, 183, and 86 acre-ft/d. The largest conveyance loss measured during 1990 in the Horse Creek Division was during summer and was 281 acre-ft/d, although a number of large daily losses also occurred during fall.

Daily rates of conveyance losses expressed in acre-feet per day per mile in the Horse Creek Division are summarized for 1990 in *B* in figure 7. The data indicate that, except for outliers, daily conveyance losses per mile during spring ranged from 2 to 9 (acre-ft/d)/mi; during summer ranged from 1 to 13 (acre-ft/d)/mi; and during fall ranged from 2 to 5 (acre-ft/d)/mi in the Horse Creek Division. The data indicate that the median conveyance loss during the three seasons is about 5, 8, and 4 (acre-ft/d)/mi. The largest conveyance loss measured during 1990 in the Horse Creek Division was during summer and was about 13 (acre-ft/d)/mi.

Division 3—Las Animas

Daily rates of conveyance losses for the 22.0 canal miles in the Las Animas Division are summarized for 1990 in *A* in figure 7. Except for outliers, the data indicate that daily conveyance losses during spring ranged from 0 to 88 acre-ft/d; during summer ranged from 176 to 308 acre-ft/d; and during fall ranged from 22 to 66 acre-ft/d in the division. The data indicate that the median conveyance loss during the three seasons is about 66, 242, and 66 acre-ft/d. The largest conveyance loss measured during 1990 in the Las Animas Division was during summer and was about 374 acre-ft/d.

Daily rates of conveyance losses expressed in acre-feet per day per mile in the Las Animas Division are summarized for 1990 in *B* in figure 7. The data indicate that, except for outliers, daily conveyance losses per mile during spring ranged from 0 to 4 (acre-ft/d)/mi; during summer ranged from 8 to 14 (acre-ft/d)/mi; and during fall ranged from 1 to 3 (acre-ft/d)/mi in the Las Animas Division. The data indicate that the median conveyance loss during the three seasons is about 3, 11, and 3 (acre-ft/d)/mi. The largest conveyance loss measured during 1990 in the Las Animas Division was during summer and was about 17 (acre-ft/d)/mi.

Division 4—Limestone

Daily rates of conveyance losses and gains for the 26.2 canal miles in the Limestone Division are summarized for 1990 in *A* in figure 7. Except for outliers, the data indicate that daily conveyance losses during spring ranged from 0 to a gain of 52 acre-ft/d; during summer ranged from a loss of 26 to a gain of 157 acre-ft/d; and during fall ranged from a loss of 26 to a gain of 26 acre-ft/d in the division. The data indicate that the median conveyance gain during the three seasons is about 26, 105, and 0 acre-ft/d. The largest conveyance loss measured during 1990 in the Limestone Division was in summer and fall and was 26 acre-ft/d. The largest conveyance gain in the division was during summer and was 157 acre-ft/d.

Daily rates of conveyance losses and gains expressed in acre-feet per day per mile in the Limestone Division are summarized for 1990 in *B* in figure 7. The data indicate that, except for outliers, daily conveyance losses per mile during the spring ranged from 0 to a gain of 2 (acre-ft/d)/mi; during summer ranged from a loss of 1 to a gain of 6 (acre-ft/d)/mi; and during fall ranged from a loss of 1 to a gain of 1 (acre-ft/d)/mi in the Limestone Division. The data indicate that the median conveyance gain during the three seasons is about 1, 4, and 0 (acre-ft/d)/mi. The largest conveyance loss measured during 1990 in the Limestone Division was in summer and fall and was 1 (acre-ft/d)/mi. The largest gain occurred during summer and was 6 (acre-ft/d)/mi.

Division 5—Lamar

The lack of good traveltime data during either irrigation year prevented statistical analysis of the conveyance losses during 1990 for the 26.8 canal miles in the Lamar Division. However, some computations were made of the daily conveyance losses using flow data from a few seepage investigations that were done in the Lamar Division. The conveyance losses estimated during the investigations ranged from about 11 to as much as 370 acre-ft/d in the Lamar Division. However, because of the short time period that was involved in the flow measurements, the combination of measurement errors from the small fluctuations that existed in the canal flow may have a large effect on the loss estimates for the Lamar Division.

Total Conveyance Losses

As previously mentioned in the "Conveyance Losses" section, a significant statistical relation does exist between the canal discharge or canal water stage and the daily rate of conveyance losses. The trend of the data in figure 7 indicates that the largest conveyance losses generally corresponded to seasons that have the largest canal flows and highest canal stage. The daily measurements indicate that conveyance losses in the three upstream divisions generally were larger during summer than during spring and fall (fig. 7). In the Limestone Division, the largest gains of water also occurred during summer. If the canal sides and bottom are permeable, seepage loss of surface water generally will increase as depth of water and capacity of the canal increases. An increase in canal water stage generally occurs during summer in the Fort Lyon Canal during the transport of large quantities of water that are needed to satisfy irrigation demand of the actively growing crops throughout the study area. The conveyance losses observed during summer indicate the effect that larger flows and higher water stage have on increasing the rate of conveyance loss and gain in the Fort Lyon Canal.

The effect that a higher water stage in the canal has on conveyance losses is best seen in the Las Animas Division during the summer of 1990 (*A* in fig. 7). During June through August, supplemental inflow of irrigation water released from Adobe Creek Reservoir is added to the river water being transported in the Fort Lyon Canal, near the end of the Horse Creek Division. The summer of 1990 (June–August), which had the largest flow of water in the Las Animas Division (*C* in fig. 5), also had the largest conveyance losses for the division. A median conveyance-loss rate of 11 (acre-ft/d)/mi was determined for the Las Animas Division during summer, which corresponds to a 3.7-times greater loss rate than computed for spring and fall in the division.

Comparison of the four divisions in *B* in figure 7 indicates that the largest conveyance losses per mile were in the La Junta Division and generally decreased in each subsequent downstream division. Because of the variation in lithology along and under the Fort Lyon Canal, daily conveyance losses are expected to be largest in areas where the canal bottom is underlain by large deposits of sand and gravel materials. The dominant bed material could be coarser under the canal in the La Junta Division because of the location of the canal in the alluvium of the Arkansas River. As the canal continues eastward, it generally is located on a terrace formation and is farther from the coarse pebble to gravel materials located in the river bottoms. The eastern divisions of the canal generally are underlain by finer grained sand and silt that are more common to the uplands in the study area. Additionally, the bottom material in the canal channel may grade into finer grained sediment as the available flow energy necessary to transport the larger size sediments is decreased in the more eastern divisions. The finer grained sediment in and under the canal, when combined with a lower water stage, probably is responsible for the smaller conveyance losses (acre-feet per day per mile) that likely occur in the eastern divisions. However, extensive maintenance operations in parts of the La Junta Division prior to the 1990 irrigation year also may have disturbed the bottom seal of the canal and contributed to the larger conveyance losses that were measured in the first division of the canal.

GROUND-WATER WITHDRAWALS

Ground-water withdrawals for irrigation frequently supplement surface-water withdrawals in the study area. There are a large number of irrigation wells in the study area, but the percentage of irrigated acreage supplied by wells generally is larger for western divisions than for eastern divisions (fig. 8). Because most of the acreage in the La Junta and the Horse Creek Divisions is located near the flood plain of the Arkansas River (right side of fig. 2), small well pumps and electric motors generally are used to lift water to the fields and distribution ditches in these two divisions. In the Horse Creek Division, there are only a few active wells because the natural channels of Horse Creek and Adobe Creek produce a high-water table through much of the central area of the division. Near the western end of the Las Animas Division, the width and the thickness of the valley-fill aquifer increases; therefore, the Las Animas Division has more terrace wells (center of fig. 2). Generally, large pumps and electric motors are used in these wells to lift water to the higher land surface. In the Limestone and the Lamar Divisions, the wells are located mainly in irrigated areas having a shallow depth to the water table. In the Limestone Division, many small wells are distributed along the division boundary that separates the Limestone and Lamar Divisions, and a few small wells are located above the Fort Lyon Canal and near the

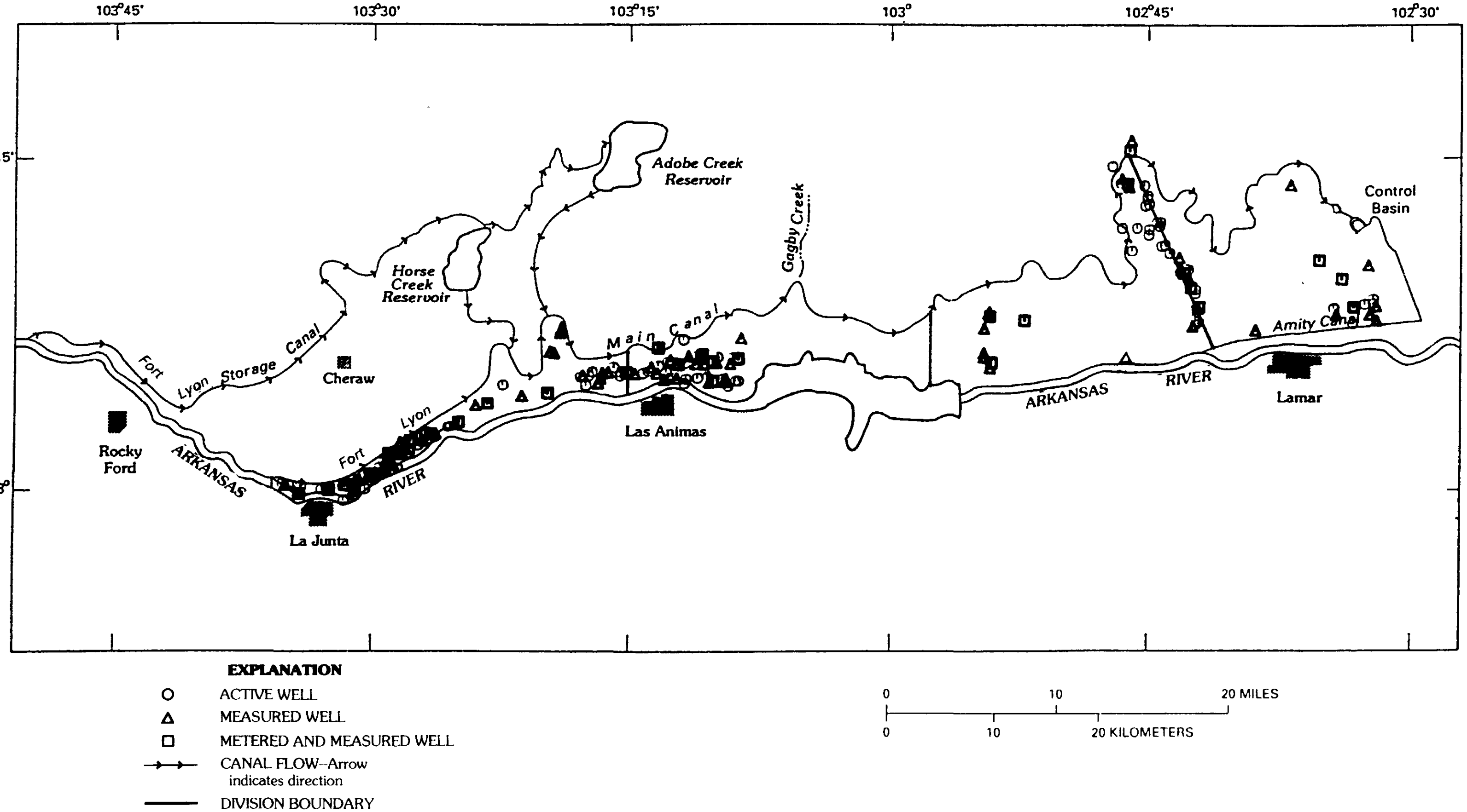


Figure 8. General distribution of wells in the study area near the Fort Lyon Canal, 1989–90.

western end of the division. In the Lamar Division, many small wells are distributed along the division boundary, and about a dozen large wells are located in the terrace areas near the eastern end of the division.

Ground-water withdrawals were estimated using a statistical sampling technique (Luckey, 1972) in which total pumpage was determined on the basis of a random sampling of active ground-water wells. A field inventory during 1989 indicated that irrigation water generally was withdrawn in the study area at 218 active wells with pumps that had electrical motors. The *kilowatt-hours* of electricity that were consumed monthly during 1989 and 1990 at a random sampling of 93 of the active wells was converted into acre-feet of pumped water using a power conversion factor. The power conversion factor was expressed as the kilowatt-hours of electricity that were needed to pump an acre-foot of water under the operating conditions that existed at the well during the pump test.

Power conversion factors were developed at each selected well site during 1990 by combining the instantaneous power consumption rate with a measurement of the flow rate. The power conversion factors ranged from 31 to 225 kWh/acre-ft at the 93 turbine and submersible irrigation pumps measured in the study area. At least two methods of flow measurement were used to determine the instantaneous flow rate at each well site. Ground-water discharge ranged from about 85 to 2,250 gal/min at the 93 wells measured in the study area. On the basis of the two flow measurements, 7 percent of the measurements were rated as ±5 percent, 78 percent were rated as ±10 percent, 6 percent were rated as ±15 percent, and the remaining 9 percent were rated as having greater than a 15 percent accuracy in the measured flow rate. At many wells, the water was lifted to the land surface from a depth of less than 50 ft, which decreases the occurrence of large annual changes in the power conversion factor that could result from the effects of a large water-level change during the irrigation season.

The use of a constant power conversion factor to estimate the annual volume of water pumped at a well site is based on the assumption that the relation is constant between the instantaneous flow rate and the power consumption rate (Hurr and Litke, 1989). Electronic running-time meters (hour-meters) were installed during 1990 at 30 randomly selected metered well locations (fig. 8) to provide an independent determination of the time (hours) of pump operation. To determine the accuracy of the withdrawal computations, using the power records and a constant power conversion factor, *calculated time* of pump operation was compared with *metered time* of pump operation at the 30 metered wells (fig. 9). The total metered time of pump operation at the 30 wells ranged from 0 to 3,580 hours during 1990. The results of the time comparison test support the use of electrical power consumption and a constant power conversion factor (rate-time technique) in this study to determine ground-water withdrawals at each measured well during both calendar years. The calculated pump time, determined using a constant power conversion factor, seems to be accurate within ±15 percent of the metered operation time, after the data is screened for unusual applications. All of the data points located outside the ±15-percent error lines shown in figure 9 were affected by the use of another irrigation pump using the electrical meter, by erroneous vibration detected by the hour-meter at the well site, and in a couple of cases by inoperative electrical company meters.

Because of the differences in the well distribution in each of the five canal divisions, potential differences in the areal withdrawal characteristics between divisions was investigated. The monthly pumpage data were ranked by division and analyzed using the Kruskal-Wallis (Minitab, Inc., 1989) nonparametric statistical test to determine if spatial variation in ground-water withdrawals was detected; the test indicated that there was a significant difference, at the 95-percent confidence level, in the monthly ground-water withdrawals between the canal divisions. To estimate the total monthly ground-water withdrawal for each canal division, the monthly mean ground-water withdrawal computed from the measured well network was multiplied by the number of active wells that was determined for the division.

Division 1—La Junta

Active wells were distributed throughout the La Junta Division allowing all the crop acreage to be irrigated by ground-water withdrawals when supplemental irrigation was needed. Well density averaged about 11.9 wells per irrigated square mile of ground-water acreage in the La Junta Division. Pump-efficiency information was collected at 14 wells in the La Junta Division, which included about 35 percent of the active wells in the division, during the study. The power conversion factor at measured wells in the division ranged from 39 to 175 kWh/acre-ft; the median was 80 kWh/acre-ft. Ground-water discharge ranged from 274 to 1,256 gal/min; the median yield was 621 gal/min at the 14 measured wells in the La Junta Division.

Ground-water withdrawals for the La Junta Division are shown by month in *A* in figure 5. Total annual ground-water withdrawals for supplemental irrigation in the division were 4,150 acre-ft in 1989

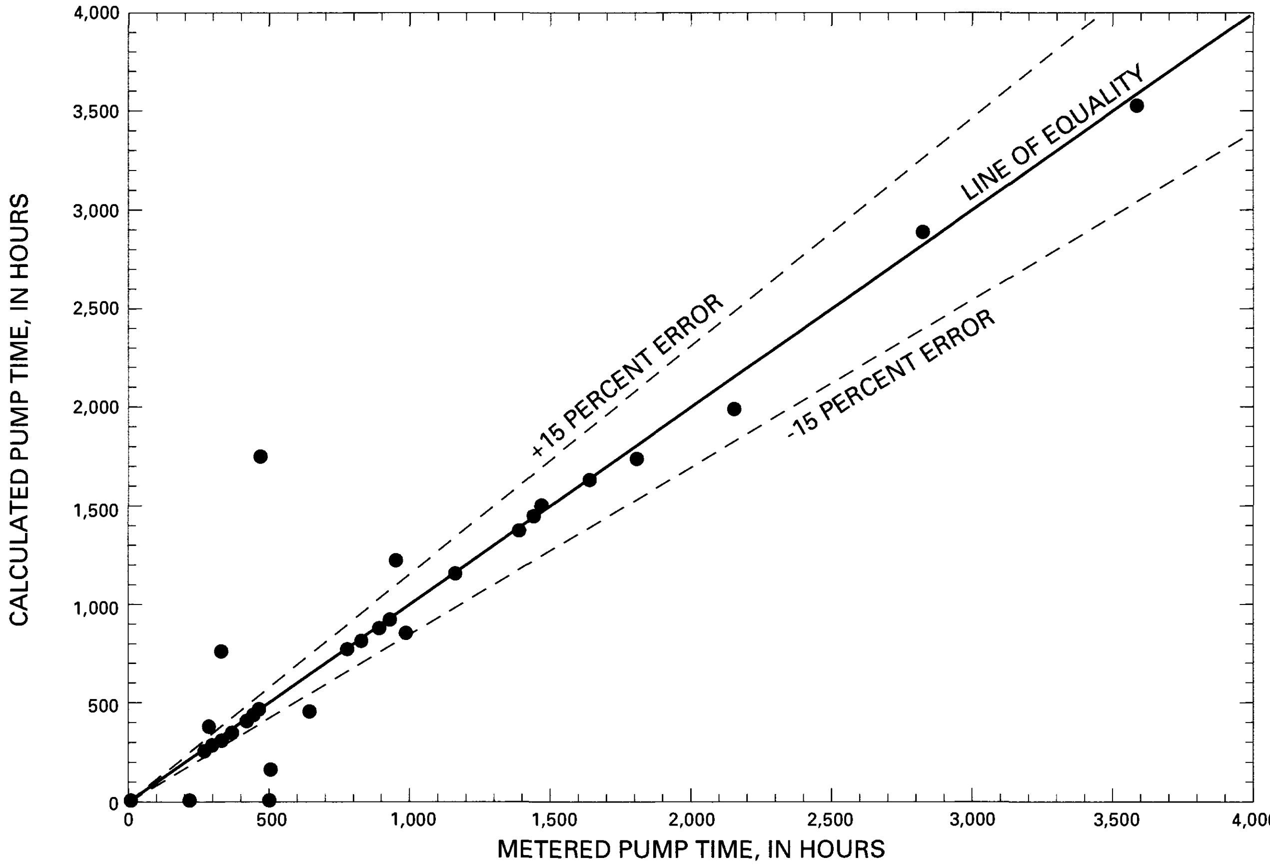


Figure 9. Relation of calculated to metered pump time at metered wells in the study area near the Fort Lyon Canal, 1990.

and 4,290 acre-ft in 1990. Ground-water withdrawals supplied about 26 percent of the total irrigation withdrawals in the La Junta Division during the study period. During the irrigation season, ground-water withdrawals ranged from 11 acre-ft in November 1989 to 1,183 acre-ft in July 1990 (*A* in fig. 5). Ground-water withdrawals during December through February reached a maximum of 9 acre-ft/mo during the study and most likely were used for irrigating pastureland and for watering livestock.

Ground-water withdrawals were used to supplement surface-water withdrawals during every month of the irrigation season. Maximum ground-water withdrawals occurred in July, August, and September of both years (*A* in fig. 5). The large ground-water withdrawals were consistent with a large crop demand during the hot months of summer and as the surface-water supply decreased. The annual pumpage pattern included large withdrawals in April, some decline when the availability of surface water improved in May and June, and then a large increase to meet the consumptive-use demand of crops during July through September (*A* in fig. 5). Ground-water withdrawals decreased in October when the harvest of crops began in the division and then remained small through the end of both years.

Division 2—Horse Creek

Ground-water withdrawals could be distributed to most of the irrigated acreage in the Horse Creek Division when supplemental irrigation was needed. Well density averaged about 3.9 wells per irrigated square mile of ground-water acreage in the Horse Creek Division. Pump-efficiency information was collected at 29 wells in the Horse Creek Division, which included about 51 percent of the active pumps in the division, during the study. The power conversion factor at measured wells in the division ranged from 60 to 177 kWh/acre-ft; the median was 112 kWh/acre-ft. Ground-water discharge ranged from 327 to 1,043 gal/min; the median yield was 609 gal/min at the 29 measured wells in the Horse Creek Division.

Ground-water withdrawals for the Horse Creek Division are shown by month in *B* in figure 5. Total annual ground-water withdrawals for supplemental irrigation in the division were 8,330 acre-ft in 1989 and 7,440 acre-ft in 1990. Ground-water withdrawals supplied about 20 percent of the total irrigation withdrawals in the Horse Creek Division during the study period. During the irrigation season, ground-water withdrawals ranged from no withdrawals during March 1990 to 1,920 acre-ft in July 1990 (*B* in fig. 5). Ground-water withdrawals during December through February reached a maximum of 22 acre-ft/mo during the study and most likely were used for irrigating pastureland and for watering livestock.

Maximum ground-water withdrawals occurred in July, August, and September of both years (*B* in fig. 5). The large ground-water withdrawals were consistent with a large crop demand for water that exists during summer. The annual pumpage pattern was similar to that for the La Junta Division, most likely indicating the concurrent surface-water irrigation of cropland that occurs in the two divisions. The annual pumpage pattern includes moderate ground-water withdrawals early in the irrigation season, some decline as surface-water availability improved in June, and then a large increase to meet the consumptive-use demand of crops during July through September. Ground-water withdrawals decreased in October when the crop harvest began, and then remained small through the end of both years. Ground-water withdrawals often were used to supplement surface-water withdrawals, but also can supply a substantial quantity of irrigation water when surface-water flow is small. For example, there was a large withdrawal in July 1990 to supply water for crop consumptive use as the surface-water supply declined in the Fort Lyon Canal (*B* in fig. 5).

Division 3—Las Animas

Ground-water withdrawals could be distributed to most of the irrigated acreage in the Las Animas Division when supplemental irrigation was needed. Well density averaged about 2.2 wells per irrigated square mile of ground-water acreage in the Las Animas Division. Pump-efficiency information was collected at 23 wells in the Las Animas Division, which included about 49 percent of the active wells in the division, during the study. The power conversion factor at measured wells in the division ranged from 31 to 187 kWh/acre-ft; the median was 125 kWh/acre-ft. Ground-water discharge ranged from 139 to 2,250 gal/min; the median yield was 906 gal/min at the 23 measured wells in the Las Animas Division.

Ground-water withdrawals for the Las Animas Division are shown by month in *C* in figure 5. Total annual ground-water withdrawals for supplemental irrigation in the division were 11,550 acre-ft in 1989 and 8,520 acre-ft in 1990. Ground-water withdrawals supplied about 17 percent of the total irrigation withdrawals in the Las Animas Division during the study period. During the irrigation season, ground-water withdrawals ranged from 6 acre-ft in March 1990 to 3,346 acre-ft in August 1989 (*C* in fig. 5). Ground-water withdrawals during December through February ranged from 8 to 20 acre-ft during the study and most likely were used for irrigating pastureland and for watering livestock.

An extended period of low precipitation in the Las Animas Division is indicated by the large ground-water withdrawals in April 1989 (*C* in fig. 5). The large ground-water withdrawals that occurred in July, August, and September of both years are consistent with a large crop demand for water during these summer months. The annual pumpage pattern includes ground-water withdrawals that begin early in the irrigation season, increase considerably in May and June, and then show a large increase to meet the consumptive-use demand of crops during July through September as the surface-water flow generally declines. The ground-water withdrawals decreased in October during the harvest of many crops in the division and remained small through the end of both years. Ground-water withdrawals were frequently used to supplement surface-water withdrawals but could provide substantial quantities of water when surface-water flow is small. An excellent example is the large withdrawal in August 1989 (*C* in fig. 5) to supply crop consumptive-use water when precipitation was small (fig. 3), and the deliveries of water to other divisions caused the canal surface-water supply to decline in the Las Animas Division.

Division 4—Limestone

Well density averaged about 2.1 wells per irrigated square mile of ground-water acreage in the Limestone Division. Most of the wells in the Limestone Division are distributed along a drainage ditch that generally separates the Limestone and Lamar Divisions. This concentrated well distribution restricted the number of irrigated acres in the Limestone Division that could be serviced by the active wells. Pump-efficiency information was collected at 17 wells in the Limestone Division, which included about 46 percent of the active wells in the division, during the study. The power conversion factor at measured wells in the division ranged from 33 to 225 kWh/acre-ft; the median was 105 kWh/acre-ft. Ground-water discharge ranged from 85 to 894 gal/min; the median yield was 516 gal/min at the 17 measured wells in the Limestone Division.

Ground-water withdrawals for the Limestone Division are shown by month in *D* in figure 5. Total annual ground-water withdrawals for supplemental irrigation in the division were 5,630 acre-ft in 1989 and 4,750 acre-ft in 1990. Ground-water withdrawals supplied about 10 percent of the total irrigation withdrawals in the division during the study period. During the irrigation season, ground-water withdrawals ranged from 181 acre-ft in March 1989 to 929 acre-ft in April 1989 (*D* in fig. 5). Ground-water withdrawals during December through February reached a maximum of 230 acre-ft/mo and most likely were used to supplement soil-moisture storage for the alfalfa crop in the division and for watering livestock.

Large ground-water withdrawals occurred throughout the irrigation season in the Limestone Division, and the withdrawals in July, August, and September generally were among the largest (*D* in fig. 5). The consistent monthly pattern of ground-water withdrawals reflects the alfalfa crop that dominates the acreage in the Limestone Division. Ground-water withdrawals generally were used to supplement surface-water withdrawals during the irrigation season; however, ground-water withdrawals also provided a substantial quantity of water during March 1990 when surface-water flow was small (*D* in fig. 5). The extended period of low precipitation in the Limestone Division is indicated by the large ground-water withdrawals in April 1989 (*D* in fig. 5).

Division 5—Lamar

Well density averaged about 1.9 wells per irrigated square mile of ground-water acreage in the Lamar Division. Many of the wells in the Lamar Division are distributed along a drainage ditch that generally separates the Limestone and Lamar Divisions. The concentrated well distribution restricted the number of irrigated acres in the Lamar Division that could be serviced by the active wells. Pump-efficiency information was collected at 10 wells in the Lamar Division, which included about 29 percent of the active wells in the division, during the study. The power conversion factor at measured wells in the division ranged from 67 to 200 kWh/acre-ft; the median was 135 kWh/acre-ft. Ground-water discharge ranged from 302 to 1,275 gal/min; the median yield was 624 gal/min at the 10 measured wells in the Lamar Division.

Ground-water withdrawals for the Lamar Division are shown by month in *E* in figure 5. Total annual ground-water withdrawals for supplemental irrigation in the division were 9,230 acre-ft in 1989 and 8,970 acre-ft in 1990. Ground-water withdrawals supplied about 12 percent of the total irrigation withdrawals in the Lamar Division during the study period. During the irrigation season, ground-water withdrawals ranged from 10 acre-ft in October 1990 to 2,411 acre-ft in August 1989 (*E* in fig. 5).

Ground-water withdrawals generally were used to supplement surface-water withdrawals in the Lamar Division. The largest ground-water withdrawals occurred during July and August, decreased in September, and remained small through the end of both years (*E* in fig. 5). There were no withdrawals during February and December 1989 and in January, February, and December 1990; the withdrawal of 303 acre-ft in January 1989 (*E* in fig. 5) was to supplement the dry pastureland in the division until surface water arrived in the Fort Lyon Canal. The extended period of low precipitation in this division is indicated by the large pumpage withdrawals in April 1989.

Total Ground-Water Withdrawals

Total ground-water withdrawals were 38,890 acre-ft (about 0.8 acre-ft per acre irrigated by ground water) during 1989 and 33,970 acre-ft (about 0.7 acre-ft per acre irrigated by ground water) in 1990 (table 6). Because the determination of the actual acreage irrigated from each active well was beyond the scope of this study, the ground-water acreage was estimated for the Limestone and Lamar Divisions by assuming that a maximum of 320 acres could be irrigated by each active well. Maximum withdrawals generally were during July through September in the La Junta, Horse Creek, and Las Animas Divisions and during July and August in the Limestone and Lamar Divisions (fig. 5). During the study, ground-water withdrawals generally were large early in the irrigation season to recharge soil moisture removed during winter; and when the temperature increased during the hot months of the year, ground-water withdrawals increased to provide the additional consumptive-use water needed by crops. Ground-water withdrawals constituted about 15 percent of the total irrigation supply of the Fort Lyon Canal system during the 2 years of the study.

Annual ground-water withdrawals increased about 240 percent from the La Junta Division to the Las Animas Division (table 6) as the pump motor size and the total crop acreage irrigated by ground-water increased. The general decrease in pump motor size in the Limestone Division is indicated by a decrease in the average annual ground-water withdrawal in this division. The annual ground-water withdrawal determined for an average division well was 106, 138, 214, 140, and 268 acre-ft/yr in the La Junta through the Lamar Divisions.

Table 6. Summary of annual ground-water withdrawals and ground-water irrigated cropland of the Fort Lyon Canal, by canal division, 1989–90

Division	Total ground-water withdrawals (acre-feet)		Ground-water irrigated cropland (acres)		Average ground-water withdrawals (acre-feet per acre)	
	1989	1990	1989	1990	1989	1990
La Junta	4,150	4,290	2,160	2,140	1.9	2.0
Horse Creek	8,330	7,440	9,460	9,290	0.9	0.8
Las Animas	11,550	8,520	13,840	13,960	0.8	0.6
Limestone	5,630	4,750	11,840	11,840	0.5	0.4
Lamar	9,230	8,970	10,880	10,880	0.8	0.8
FORT LYON CANAL	38,890	33,970	48,180	48,110	[1]0.8	[1]0.7

[1]Represents an area-weighted average of the five canal divisions.

During 1989 and 1990, average ground-water withdrawals per acre decreased from the La Junta Division to the Las Animas Division (table 6), which indicates the effect of lower well density and the type of distribution system. The ground-water withdrawal of more than 1.9 acre-ft/acre in the La Junta Division supports the earlier information that conveyance loss is an important component affecting irrigated acreage throughout the division. About 26 percent more water per acre was pumped in the La Junta Division during the study period than was pumped in the next two downstream divisions added together.

THEORETICAL CROP CONSUMPTIVE USE

Accurate estimates of crop consumptive use are important because of the increased competition for the limited water resources in the Arkansas River Valley. Direct field measurements of crop consumptive use are often complex and time consuming; therefore, it is seldom practical to directly determine the needed information through local field measurements. The theoretical estimates presented in this report are an effort to document typical characteristics of water use by crops grown in the study area.

In this report, consumptive use is a theoretical value that represents the maximum amount of irrigation water that can be consumed by growing crops and evaporated from the soil surface when an adequate supply of soil moisture is available. Certain shortcomings are inherent with a theoretical method of estimating crop consumptive use. The accuracy of the method used depends on a basic assumption that the crop is always well supplied with water to satisfy the maximum evapotranspiration (ET) needs. When soil water becomes limiting, the rate of crop ET will decrease and the theoretical method will then overestimate the actual ET of the crop. Because water shortages exist in the study area, there is a likelihood that crops are under-irrigated at some time during the growing season. As a result, crop consumptive-use estimates generated by a theoretical method may exceed the amounts of water actually used by crops.

Cultural practices in an area also are involved in the actual rate of crop consumptive use. Water management, and especially, irrigation timing often are major factors affecting the accuracy of consumptive-use estimates in the Arkansas River Valley (Don Miles, Colorado State University Extension Service (retired), oral commun., 1990). Therefore, the actual crop consumptive use in the study area may be substantially different from the theoretical value and can only be determined by locally calibrating the theoretical estimate to the measured consumptive use for each crop in question. This crop calibration was not made for the consumptive-use estimates presented in this report. The estimates presented in this report for theoretical crop consumptive use, hereafter called crop consumptive use, and for the theoretical *crop irrigation requirement*, hereafter called crop irrigation requirement, were checked for reasonableness by comparison to published information for the area (U.S. Soil Conservation Service, 1988).

Blaney and Criddle (1950) developed a temperature-based meteorological method to estimate crop consumptive use that has been used extensively in the western United States. The modified Blaney-Criddle method that was used is described in a report by the U.S. Soil Conservation Service (1970). Input data included the average monthly temperature, monthly precipitation, frost dates, crop growth-stage coefficients, and crop growing season parameters. *Effective precipitation* was calculated using a method in which small rainstorms were almost totally effective in decreasing the net irrigation requirement, whereas the larger rainstorms had a smaller net effectiveness because of the higher losses that result from surface runoff. Soil-moisture carryover between irrigation seasons was excluded during the theoretical consumptive-use estimation because of the extremely limited non-growing-season precipitation that occurs in the study area (fig. 3). Other consumptive-use methods also were available that included the climatic variables of solar radiation, humidity, and wind. The additional data that are needed for the use of these more detailed meteorological-based methods of estimating crop consumptive use were not available in the study area and were beyond the scope of the study to measure.

Theoretical consumptive use was estimated on a monthly basis for crop acreage irrigated by the Fort Lyon Canal during 1989 and 1990. The modified Blaney-Criddle method required that monthly precipitation and temperature be measured (fig. 3) and required the divisional distribution of irrigated cropland that is provided in table 11 in the "Supplemental Data" section at the back of this report. The total acreage irrigated by the Fort Lyon Canal was between 91,580 and 91,670 acres during the study (table 11). Alfalfa was the largest irrigated crop cultivated in the study area (about 61 percent of irrigated acreage averaged during the study period,), sorghum was the second largest (about 13 percent), and corn was the third largest (about 9 percent). The other staple crops cultivated in the study area are wheat (about 6 percent), pasture (about 2 percent), and spring grains (about 1 percent). *Fallow land* (about 6 percent) and acreage of unknown crop use (about 1 percent) composed the remaining irrigated acreage in the study area (total acreage does not equal 100 percent because of independent rounding). Excluded from the crop consumptive-use analysis is the irrigated acreage set aside as fallow land and the irrigated acreage of unknown crop use (table 11). Information was not available to estimate the consumptive use for either of these last two uses, which amounted to about a 7-percent decrease in the irrigated acreage in the theoretical crop consumptive-use analysis. Crop acreage included in the analysis was alfalfa, sorghum, corn, wheat, pasture, and spring grains and was about 84,880 acres in 1989 and about 85,380 acres in 1990.

The percentage of land in the five canal divisions used for crop acreage and other acreage is shown in figure 10. Alfalfa was grown on the largest percentage of the irrigated acreage in all five of the Fort Lyon Canal divisions during the study (fig. 10). The cropping pattern varied in the canal divisions during the 2 study years and was affected by projections of water availability and the particular crop programs that were available to the landowners in the study area during each year. Information needed to define the extent of subirrigated land located in the study area was not obtained. Field observations indicated, however, that subirrigated land generally was used for alfalfa acreage in the Limestone and Lamar Divisions of the Fort Lyon Canal.

Comparisons of the annual water-use rates for an intended crop use at harvest time indicated that crop consumptive use seldom differs by more than 20 percent annually, regardless of the final use at harvest. Although sorghum and corn were classified in the computations as two grain crops, each crop also was grown for use as a forage crop in the study area. Available county data indicated that grain corn was about 85 percent of the corn acreage near the western end of the study area in Otero County and decreased to about 75 percent of the corn acreage near the eastern end of the study area in Prowers County (Colorado Cooperative Crop and Livestock Reporting Service, 1990). Although the annual rate of water use can be as much as 15 percent greater for alfalfa production when compared to other types of hay crops grown in the study area, all hay acreage was grouped together as alfalfa acreage when estimating consumptive use for the crop. Available data for the three counties in the study area indicated that alfalfa ranged from 90 to 96 percent of the hay acreage that was grown (Colorado Cooperative Crop and Livestock Reporting Service, 1990). About 37 percent of the pastureland in the study area was in the Horse Creek Division (table 11), mainly around areas that border Horse Creek and Adobe Creek. The remaining pastureland was distributed about evenly throughout the farmstead areas in the other four canal divisions. The wheat grown in the study area generally is winter wheat varieties because the spring wheat varieties often produce poorly in the Arkansas River Valley (Lorenz Sutherland, Soil Conservation Service, oral commun., 1990). About 78 percent of the wheat and about 83 percent of the spring grains were grown east of John Martin Reservoir in the Limestone and Lamar Divisions (table 11). Spring grains in the study area included 60-percent oats acreage and 40-percent barley acreage, which generally were planted as cover crops for alfalfa during the first year.

Division 1—La Junta

Crop consumptive use, effective precipitation, and crop irrigation requirement for the La Junta Division are shown by month in *A* in figure 11. Crop consumptive use in the division was 4,900 acre-ft dur-

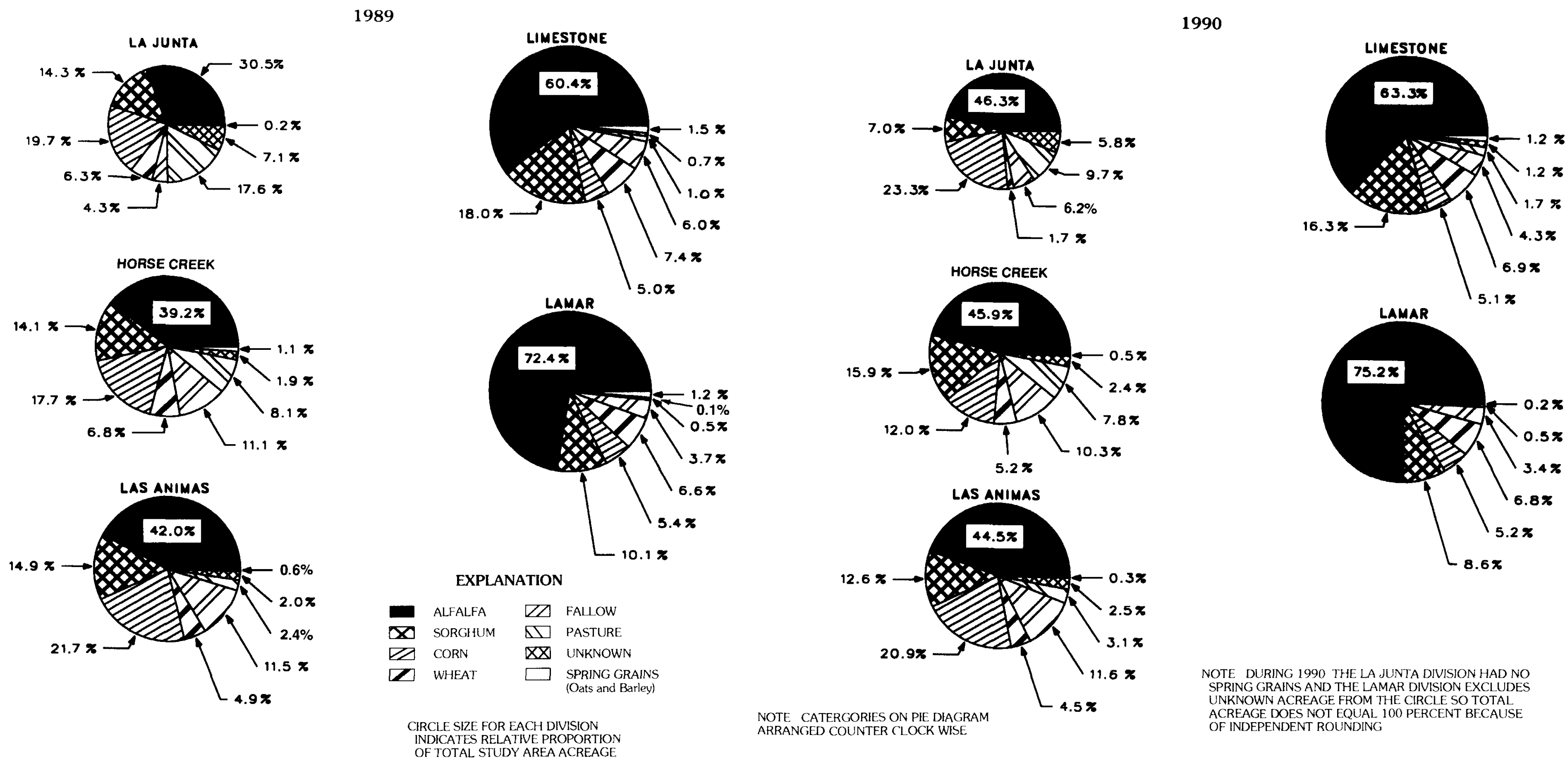


Figure 10. Crop acreage and other acreage near the Fort Lyon Canal, by canal division, 1989–90.

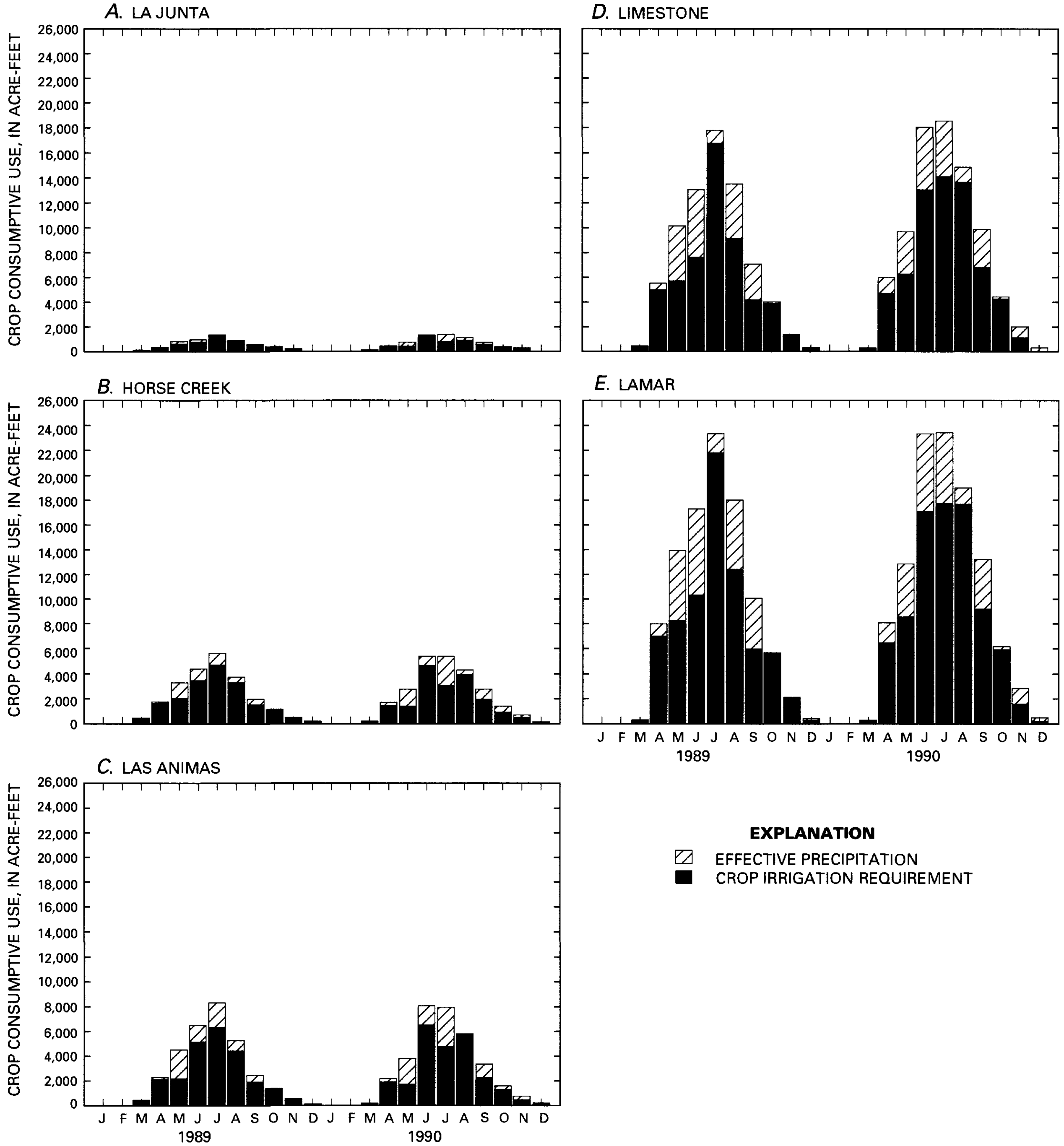


Figure 11. Monthly theoretical crop consumptive use, effective precipitation, and theoretical crop irrigation requirement near the Fort Lyon Canal, by canal division (*A*, La Junta; *B*, Horse Creek; *C*, Las Animas; *D*, Limestone; *E*, Lamar), 1989–90.

ing 1989 and 5,260 acre-ft during 1990. During the irrigation season, crop consumptive use ranged from 14 acre-ft in March 1990 to 1,280 acre-ft in July 1989 (*A* in fig. 11). Crop consumptive use was small from January through March and during December of both years and reached a maximum of 94 acre-ft in March 1989 for these months. Crop consumptive use generally increased steadily from April through July of both study years; the maximum use was 1,280 acre-ft in July 1989 and 1,260 acre-ft in July 1990. Crop consumptive use decreased to 840 acre-ft in August 1989 and 960 acre-ft in August 1990 and then continued to decrease steadily through the end of both years. Crop harvest in the La Junta Division is indicated by the decrease in crop consumptive use that occurs after September in both years.

Air temperature and precipitation data measured only at site W1 (fig. 1) were used in the crop consumptive-use calculations for the La Junta Division. Effective precipitation generally contributed little to decrease the crop irrigation requirement in the division. Effective precipitation contributed 750 acre-ft during 1989 and 1,510 acre-ft during 1990 towards the crop consumptive use in the division. During 1990, the monthly effect of precipitation is indicated in *A* in figure 11 by the substantial lowering of the crop irrigation requirement in July. Although effective precipitation contributed only 75 acre-ft to crop consumptive use during June 1990, the wet July 1990 that followed supplied 632 acre-ft of water towards crop consumptive use.

Crop irrigation requirement was determined by subtracting effective precipitation from crop consumptive use. Crop irrigation requirement in the La Junta Division was 4,150 acre-ft in 1989 and 3,750 acre-ft in 1990. During the irrigation season, crop irrigation requirement ranged from 9 acre-ft during March 1990 to 1,220 acre-ft in July 1989 (*A* in fig. 11). A comparison of crop irrigation requirement in the La Junta Division (table 7) to total surface- (table 5) and ground-water withdrawals (table 6) used for irrigation, excluding conveyance losses, indicates that an adequate water supply was available on an annual basis to meet crop irrigation needs during both years of the study.

Division 2—Horse Creek

Crop consumptive use, effective precipitation, and crop irrigation requirement in the Horse Creek Division are shown by month in *B* in figure 11. Crop consumptive use in the division was 21,460 acre-ft during 1989 and 22,470 acre-ft during 1990. During the irrigation season, crop consumptive use ranged from 95 acre-ft in March 1990 to 5,430 acre-ft in July 1989 (*B* in fig. 11). Crop consumptive use was small from January through March and during December of both years and reached a maximum of 380 acre-ft during March 1989 for these months. Crop consumptive use increased steadily from April through July during both study years; the maximum use was 5,430 acre-ft in July 1989 and 5,160 acre-ft in July 1990. Crop consumptive use decreased to 3,610 acre-ft in August 1989 and 4,070 acre-ft in August 1990 and then continued to decrease steadily through the end of both years. As in the La Junta Division, crop harvest in the Horse Creek Division decreased crop consumptive use after September of both years.

Air temperature and precipitation data from site W1 and site W2 (fig. 1) were used in the crop consumptive-use calculations for the Horse Creek Division. Effective precipitation generally contributed more water to decrease the crop irrigation requirement than had occurred in the La Junta Division. Effective precipitation contributed 4,160 acre-ft during 1989 and 6,240 acre-ft during 1990 towards the crop consumptive use in the division. The monthly effect of precipitation is indicated in *B* in figure 11 by the substantial lowering of the crop irrigation requirement during May of both years and again in July 1990. Effective precipitation contributed 1,270 acre-ft to crop consumptive use in May 1990 and 2,300 acre-ft during July 1990.

Crop irrigation requirement in the Horse Creek Division was 17,300 acre-ft in 1989 and 16,230 acre-ft in 1990. During the irrigation season, crop irrigation requirement ranged from 60 acre-ft during March 1990 to 4,590 acre-ft in July 1989 (*B* in fig. 11). A comparison of crop irrigation requirement in the Horse Creek Division (table 7) to total surface- (table 5) and ground-water withdrawals (table 6) used for irrigation, excluding conveyance losses, indicates that an adequate water supply was available on an annual basis to meet crop irrigation needs during both years of the study.

Division 3—Las Animas

Crop consumptive use, effective precipitation, and crop irrigation requirement in the Las Animas Division are shown by month in *C* in figure 11. Crop consumptive use in the division was 31,270 acre-ft during 1989 and 32,720 acre-ft during 1990. During the irrigation season, crop consumptive use ranged from 100 acre-ft in March 1990 to 8,130 in July 1989 (*C* in fig. 11). Crop consumptive use was small from January through March and during December of both years and reached a maximum of 460 acre-ft in March 1989 for these months. Crop consumptive use

Table 7. Summary of annual theoretical crop consumptive use, crop acreage, and theoretical crop irrigation requirement of the Fort Lyon Canal, by canal division, 1989–90

[Crop acreage includes alfalfa, spring grains, corn, sorghum, wheat, and pasture, as listed in table 11. Values are rounded]

Division	Total crop consumptive use (acre-feet)		Average crop consumptive use (acre-feet per acre)		Crop acreage (acres)		Total crop irrigation requirement (acre-feet)		Average crop irrigation requirement (acre-feet per acre)	
	1989	1990	1989	1990	1989	1990	1989	1990	1989	1990
La Junta	4,900	5,260	2.6	2.8	1,920	1,880	4,150	3,750	2.2	2.0
Horse Creek	21,460	22,470	2.6	2.8	8,230	8,110	17,300	16,230	2.1	2.0
Las Animas	31,270	32,720	2.6	2.7	11,960	12,000	24,260	23,960	2.0	2.0
Limestone	71,970	82,390	2.6	2.9	27,460	28,260	53,300	62,970	1.9	2.2
Lamar	97,930	108,290	2.8	3.1	35,310	35,130	73,090	83,140	2.1	2.4
FORT LYON CANAL	227,530	251,130	[1]2.7	[1]2.9	84,880	85,380	172,100	190,050	[1]2.0	[1]2.2

[1]Represents an area-weighted average of the five canal divisions.

generally increased steadily from April through July of both years; the maximum use in July 1990 was 7,800 acre-ft. Crop consumptive use decreased to 5,200 acre-ft in August 1989 and 5,660 acre-ft in August 1990 and then continued to decrease steadily through the end of both years. Crop harvest in the Las Animas Division rapidly decreased crop consumptive use after September of both years, although some water was needed by alfalfa, wheat, and pasture acreage through the end of both years (*C* in fig. 11).

Air temperature and precipitation data measured only at site W2 (fig. 1) were used in the crop consumptive-use calculations for the Las Animas Division. Effective precipitation contributed a substantial amount of water that decreased the crop irrigation requirement in the division. Effective precipitation contributed 7,010 acre-ft during 1989 and 8,760 acre-ft during 1990 towards crop consumptive use in the Las Animas Division. The monthly effect of precipitation is indicated in *C* in figure 11 by the substantial lowering of the irrigation demand in May of both years and again in July 1990. Effective precipitation contributed 2,300 acre-ft in May 1989 and 2,120 acre-ft in May 1990. After a wet July in 1990 that supplied 3,080 acre-ft to crop consumptive use, a dry August followed (fig. 3) that provided almost no effective precipitation contribution to crop consumptive use in the Las Animas Division (*C* in fig. 11).

Crop irrigation requirement in the Las Animas Division was 24,260 acre-ft in 1989 and 23,960 acre-ft in 1990. During the irrigation season, crop irrigation requirement ranged from 70 acre-ft during March 1990 to 6,390 acre-ft in June 1990 (*C* in fig. 11). A comparison of crop irrigation requirement in the Las Animas Division (table 7) to total surface- (table 5) and groundwater withdrawals (table 6) used for irrigation, excluding conveyance losses, indicates that an adequate water supply was available on an annual basis to meet crop irrigation needs during both years of the study.

Division 4—Limestone

Crop consumptive use, effective precipitation, and crop irrigation requirement in the Limestone Division are shown by month in *D* in figure 11. Crop consumptive use in the division was 71,970 acre-ft during 1989 and 82,390 acre-ft during 1990. During the irrigation season, crop consumptive use ranged from 210 acre-ft in March 1990 to 18,320 acre-ft in July 1990 (*D* in fig. 11). Crop consumptive use was small from January through March and during December of both years and reached a maximum of 300 acre-ft during March 1989 for these months. Crop consumptive use increased rapidly in April and then increased steadily through July of both years; the maximum use in July 1989 was 17,600 acre-ft. Crop consumptive use decreased to 13,320 acre-ft in August 1989 and 14,620 acre-ft in August 1990 and then continued to decrease steadily through the end of both years. Crop harvest in the Limestone Division rapidly decreased crop consumptive use after September of both years, although substantial water was still needed by alfalfa and wheat acreage in the division through the end of both years (*D* in fig. 11).

Air temperature and precipitation data measured only at site W4 (fig. 1) were used in the crop consumptive-use calculations for the Limestone Division. Effective precipitation contributed a substantial amount of water to decrease the crop irrigation requirement in the division. Effective precipitation contributed 18,670 acre-ft during 1989 and 19,420 acre-ft during 1990 of water to crop consumptive use in the Limestone Division. The monthly effect of precipitation is indicated in *D* in figure 11 by the substantial lowering of the crop irrigation requirement during 8 months of the 1989 and 1990 irrigation seasons.

Crop irrigation requirement in the Limestone Division was 53,300 acre-ft in 1989 and 62,970 acre-ft in 1990. During the irrigation season, crop irrigation requirement ranged from 160 acre-ft during March 1990 to 16,520 acre-ft in July 1989 (*D* in fig. 11). Because of the operational constraints that can delay delivery of water in a large irrigation system, an increase of irrigation water in the Fort Lyon Canal to fulfill the monthly crop irrigation requirement during July 1989 would be difficult to achieve.

A comparison of crop irrigation requirement in the Limestone Division (table 7) to total surface- (table 5) and ground-water withdrawals (table 6) used for irrigation, excluding conveyance losses, indicates that the water supply was not adequate to meet crop irrigation needs during either year of the study. These data indicate that without a supplemental water supply, crop yields could decrease. Field observations and discussions with local farmers indicated that there is some supplemental water available to crops by natural subirrigation and by the use of tail water. These sources help to supplement crop irrigation requirement in some areas of the division. Better quantification of actual water supplies, conveyance losses, and crop irrigation needs in the Limestone Division are needed to evaluate whether crops are adversely affected by a water shortage.

Division 5—Lamar

Crop consumptive use, effective precipitation, and crop irrigation requirement in the Lamar Division are shown by month in *E* in figure 11. Crop consumptive use in the division was 97,930 acre-ft during 1989 and 108,290 acre-ft during 1990. During the irrigation season, crop consumptive use ranged from 230 acre-ft in March 1990 to 23,270 acre-ft in July 1990 (*E* in fig. 11). Crop consumptive use was small from January through March and during December of both years and reached a maximum of 290 acre-ft in March 1989 for these months. Crop consumptive use increased rapidly in April and then increased steadily through July of both years; the maximum use in July 1989 was 23,160 acre-ft. Crop consumptive use decreased to 17,920 acre-ft in August 1989 and 18,880 acre-ft in August 1990 and then continued to decrease steadily through the end of both years (*E* in fig. 11). Crop harvest in the Lamar Division rapidly decreased crop consumptive use after September of both years, although substantial water was still needed by alfalfa and wheat acreage in the division through the end of both years (*E* in fig. 11).

Air temperature and precipitation data measured only at site W4 (fig. 1) were used in the crop consumptive-use calculations for the Lamar Division. Effective precipitation contributed a substantial amount of water to decrease the crop irrigation requirement in the division. Effective precipitation contributed 24,840 acre-ft during 1989 and 25,150 acre-ft during 1990 towards crop consumptive use in the Lamar Division. The monthly effect of precipitation is indicated in *E* in figure 11 by the substantial lowering of the crop irrigation requirement during different months of the 1989 and 1990 irrigation seasons.

Crop irrigation requirement in the Lamar Division was 73,090 acre-ft in 1989 and 83,140 acre-ft in 1990. During the irrigation season, crop irrigation requirement ranged from 180 acre-ft during March 1990 to 21,750 acre-ft in July 1989 (*E* in fig. 11). Because of the operational constraints that can delay delivery of water in a large irrigation system, an increase of irrigation water in the Fort Lyon Canal to fulfill the monthly crop irrigation requirement during July 1989 would be difficult to achieve.

A comparison of crop irrigation requirement in the Lamar Division (table 7) to total surface- (table 5) and ground-water withdrawals (table 6) used for irrigation, excluding conveyance losses, indicates that the water supply was not adequate to meet crop irrigation needs during either year of the study. These data indicate that without a supplemental water supply, crop yields could decrease. Field observations and discussions with local farmers indicated that there is some supplemental water available to crops by subirrigation and by the use of tail water. These sources help to supplement crop irrigation requirement in some areas of the division. Better quantification of actual water supplies, conveyance losses, and crop irrigation needs in the Lamar Division are needed to evaluate whether crops are adversely affected by a water shortage.

Total Theoretical Crop Consumptive Use

Total theoretical crop consumptive use of irrigation water by acreage in the study area was estimated at 227,530 acre-ft (about 2.7 acre-ft per acre of cropland) during 1989 and 251,130 acre-ft (about 2.9 acre-ft per acre of cropland) during 1990 (table 7). During the study years, annual crop consumptive use ranged from 2.6 acre-ft per acre of cropland in four of the divisions for 1989 (table 7) to 3.1 acre-ft per acre of cropland in the Lamar Division for 1990. The estimate of crop consumptive use increased about 10 percent from 1989 to 1990 in the study area.

Crop consumptive use generally increased from the La Junta to the Lamar Divisions as the alfalfa acreage increased toward the eastern end of the study area. The eastward increase in crop consumptive use is offset partially by about a 30-percent increase in mean annual precipitation from La Junta (site W1) to Lamar (site W4) in the study area (table 1). Precipitation increased from 1989 to 1990 in all five of the canal divisions (table 1). However, seasonal and annual variation in precipitation often is the attribute that best characterizes precipitation in the study area. The increase between the 2 years of the study varied from about 110 percent in the La Junta Division to an increase of only about 17 percent in the Lamar Division.

Effective precipitation supplied an average of about 24 percent of the total theoretical crop consumptive use during the study period. Effective precipitation contributed about 0.7 ft of water during 1989 and 1990 toward crop consumptive use throughout the study area. Although total precipitation increased about 0.3 ft (30 percent) between the 2 study years, the effective precipitation that was calculated supplied only an additional 0.1 ft toward crop consumptive use. Perhaps of greater importance, however, is the variation in effective precipitation among the canal divisions during the 2 years. During 1989, effective precipitation supplied about 0.4 ft of crop consumptive use in the La Junta Division and steadily increased eastward to about 0.7 ft in the Lamar Division. During 1990, effective precipitation supplied about 0.8 ft of crop consumptive use in the La Junta Division and then slightly decreased eastward to about 0.7 ft in the Lamar Division.

Total crop irrigation requirement was 172,100 acre-ft (about 2.0 acre-ft per acre of cropland) during 1989 and 190,050 acre-ft (about 2.2 acre-ft per acre of cropland) during 1990 (table 7). During the 2 study years, the crop irrigation requirement ranged from 1.9 acre-ft per acre of cropland to 2.4 acre-ft per acre of cropland in the five canal divisions (table 7). Although about 30 percent more precipitation was available to satisfy crop consumptive use during 1990, the increased irrigated acreage, especially the increased acreage of alfalfa grown throughout the study area during 1990 (table 11), was enough to cause total crop irrigation requirement to increase about 10 percent from 1989 to 1990.

SUMMARY

Water-use information is needed for irrigated farmland in the Arkansas River Valley of southeastern Colorado because of continuing changes in the sources and patterns of agricultural water use. The semiarid land in the area has a lengthy history of agricultural water use that dates back to the 1880's. In 1989, the U.S. Geological Survey, in cooperation with the Bent County Board of County Commissioners, began a study to evaluate irrigation water use quantitatively for about 91,630 acres of farmland irrigated from the 103.7-mi-long Fort Lyon Canal. This report provides information from 1989 and 1990 for four hydrologic components of irrigation water use, namely surface-water withdrawals, conveyance losses, ground-water withdrawals, and estimates of theoretical crop consumptive use for the study area.

Surface-water withdrawals constituted about 85 percent of total irrigation withdrawals supplied during 1989 and 1990 in the five divisions of the Fort Lyon Canal. Surface-water withdrawals for the Fort Lyon Canal were 211,150 acre-ft (about 2.3 acre-ft/acre) during 1989 and 202,000 acre-ft (about 2.2 acre-ft/acre) during 1990, a decrease in surface-water withdrawals of about 5 percent. During the study, surface-water withdrawals generally increased when air temperature increased to provide additional consumptive-use water needed by growing crops. Maximum monthly surface-water withdrawals occurred during May through August in each canal division. Of the total surface-water withdrawals, about 81 percent was supplied by diversion from the Arkansas River and about 19 percent was supplied by off-stream reservoir storage. The use of reservoir sources provided more timely deliveries of water to meet crop irrigation requirements.

Conveyance losses occurred during transport of irrigation water in the Fort Lyon Canal and likely constituted a large loss from surface-water withdrawals. Conveyance losses were determined using daily volumes of inflow and outflow collected at five continuous-record streamflow-gaging stations in the four upstream divisions of the unlined canal during periods of non-irrigation. Daily conveyance-loss data were grouped for 1990 into three seasons to account for

temporal variability detected in conveyance-loss rates. Daily mean discharge data indicated that conveyance losses were larger when a high-water stage was present in the canal. Conveyance losses in the La Junta Division were computed only when the flow was less than 300 ft^3/s, whereas the full range of measured flows were used in the Horse Creek, Las Animas, and Limestone Divisions of the canal. Conveyance losses were largest in the La Junta Division of the canal as much as 72 (acre-ft/d)/mi and generally decreased in the downstream canal divisions. Conveyance-loss rates generally ranged from 2 to 72 (acre-ft/d)/mi in the La Junta Division, from 1 to 13 (acre-ft/d)/mi in the Horse Creek Division, from 0 to 17 (acre-ft/d)/mi in the Las Animas Division, and from 1 to a gain of 6 (acre-ft/d)/mi in the Limestone Division. A maximum loss of 432 acre-ft/d of surface water was measured in the La Junta Division and a maximum gain of 157 acre-ft/d of surface water was measured in the Limestone Division during 1990.

Ground-water withdrawals constituted about 15 percent of total irrigation withdrawals supplied to the Fort Lyon Canal system during the study period. Irrigation wells generally are used as a supplemental source of water to extend the surface-water supplies, but many wells can function as the principal source of crop irrigation water during periods of water need. Ground-water withdrawals for the Fort Lyon Canal system were estimated to be 38,890 acre-ft (about 0.8 acre-ft per acre irrigated by ground water) during 1989 and 33,970 acre-ft (about 0.7 acre-ft per acre irrigated by ground water) during 1990, a decrease of about 14 percent. The pump discharge at 93 wells measured in the study area ranged from 85 to 2,250 gal/min. The annual average ground-water withdrawal ranged from 106 to 268 acre-ft per well per year at electrically powered irrigation wells in the study area.

Total theoretical crop consumptive use was estimated to be 227,530 acre-ft (about 2.7 acre-ft per acre of cropland) during 1989 and 251,130 acre-ft (about 2.9 acre-ft per acre of cropland) during 1990, an increase of about 10 percent between the 2 years. Precipitation supplements the irrigation supply in the study area with about 90 percent of annual rainfall occurring from March through September during the growing season. Effective precipitation supplied an average of about 24 percent of total theoretical crop consumptive use during the study years. Total theoretical crop irrigation requirement needed from irrigation withdrawals was 172,100 acre-ft (about 2.0 acre-ft per acre of cropland) during 1989 and 190,050 acre-ft (about 2.2 acre-ft per acre of cropland) during 1990, an increase of about 10 percent between the 2 years.

Total acreage irrigated by the Fort Lyon Canal was 91,580 acres in 1989 and 91,670 acres in 1990, an increase of about 0.1 percent in the irrigated acreage of the study area between the 2 years. Similar crops were cultivated in the five canal divisions and averaged for the study period generally included alfalfa (about 61 percent of irrigated acreage), sorghum (about 13 percent), corn (about 9 percent), wheat (about 6 percent), pasture (about 2 percent), and spring grains (about 1 percent). Fallow land (about 6 percent) and land acreage of unknown crop use (about 1 percent) composed the remaining irrigated acreage in the study area (total does not equal 100 percent because of independent rounding).

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SUPPLEMENTAL DATA

Table 8. Summary of information and daily mean discharge for streamflow-gaging station 07122005 Fort Lyon Canal near La Junta (site S1), 1989–90

[--, no data; MAX, maximum; MIN, minimum; AC-FT, acre-feet]

LOCATION.—Lat 38°00'30", long 103°34'30", in center NE 1/4 sec. 33, T. 23 S., R. 55 W., Otero County, Hydrologic Unit 11020005, on right bank about 2 miles northwest of the town of La Junta, and about 1 mile west of the road junction with Jachim Lane on the Fort Lyon Canal Service Road, and 1.1 canal miles downstream from the second diversion dam on the Fort Lyon Canal.

GAGE.—A data-collection platform (DCP) housed in a wooden and concrete structure records water-stage height from two stilling wells in hydraulic connection with a concrete standard 40-foot Parshall flume. The DCP system is powered by 115-volt alternating electrical current. The water heights also are recorded by a water-stage recorder. Outside reference is a staff plate attached to the right wall in the approach section of the flume.

Day	Daily mean discharge (cubic feet per second)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
	January through December 1989											
1	0.00	0.00	0.00	193	151	583	512	707	164	149	259	0.00
2	.00	.00	.00	176	151	777	515	654	164	150	282	.00
3	.00	.00	.00	162	151	696	514	649	159	158	285	.00
4	.00	.00	.00	176	149	726	516	651	147	166	270	.00
5	.00	.00	.00	168	150	483	516	652	163	164	281	.00
6	.00	.00	.00	138	149	469	518	653	137	164	295	.00
7	.00	.00	.00	135	149	755	568	755	126	165	300	.00
8	.00	.00	.00	160	145	630	648	708	124	162	294	.00
9	.00	.00	.00	209	147	496	515	736	137	166	303	.00
10	.00	.00	.00	186	151	639	516	625	134	165	313	.00
11	.00	.00	.00	156	153	695	512	574	164	159	310	.00
12	.00	.00	.00	167	146	776	517	576	165	162	291	.00
13	.00	.00	.00	177	148	650	514	803	170	163	277	.00
14	.00	.00	.00	168	180	607	959	571	167	166	270	.00
15	.00	.00	306	151	301	531	644	447	166	165	313	.00
16	.00	.00	499	147	852	682	360	190	164	159	346	.00
17	.00	.00	569	141	756	662	261	164	167	166	158	.00
18	.00	.00	456	143	493	509	369	169	165	164	1	.00
19	.00	.00	492	157	403	704	214	167	163	166	.00	.00
20	.00	.00	412	150	587	718	247	165	165	167	.00	.00
21	.00	.00	374	154	428	648	387	166	165	164	.00	.00
22	.00	.00	197	152	331	634	422	163	161	163	.00	.00
23	.00	.00	245	152	253	623	633	164	160	164	.00	.00
24	.00	.00	285	151	315	483	675	166	165	164	.00	.00
25	.00	.00	231	151	404	438	682	168	166	164	.00	.00
26	.00	.00	249	151	587	288	655	165	165	162	.00	.00
27	.00	.00	242	152	795	163	654	165	165	162	.00	.00
28	.00	.00	264	150	754	149	653	164	166	166	.00	.00
29	.00	--	212	151	631	148	655	169	160	166	.00	.00
30	.00	--	194	151	482	368	652	163	154	165	.00	.00

Table 8. Summary of information and daily mean discharge for streamflow-gaging station 07122005 Fort Lyon Canal near La Junta (site S1), 1989–90--Continued

Day	Daily mean discharge (cubic feet per second)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
	January through December 1989—Continued											
31	0.00	--	196	--	369	--	719	165	--	217	--	0.00
MEAN	.00	0.00	175	159	350	558	539	401	158	165	162	.00
MAX	.00	.00	569	209	852	777	959	803	170	217	346	.00
MIN	.00	.00	.00	135	145	148	214	163	124	149	.00	.00
AC-FT	.00	.00	10,760	9,470	21,540	33,180	33,170	24,660	9,400	10,120	9,620	.00
	January through December 1990											
1	.00	.00	.00	345	259	820	463	759	137	151	557	--
2	.00	.00	.00	345	261	831	409	632	148	155	541	--
3	.00	.00	.00	281	428	505	349	473	152	155	597	--
4	.00	.00	.00	241	767	659	182	401	143	156	597	--
5	.00	.00	.00	211	938	623	167	593	133	186	676	--
6	.00	.00	.00	237	591	585	167	686	142	153	627	--
7	.00	.00	.00	262	234	688	582	702	152	154	610	--
8	.00	.00	.00	236	422	745	950	264	161	155	665	--
9	.00	.00	.00	182	794	717	692	152	153	155	656	--
10	.00	.00	.00	161	485	743	480	153	155	158	657	--
11	.00	.00	.00	139	306	877	845	157	154	163	667	--
12	.00	.00	.00	146	224	860	725	156	153	155	632	--
13	.00	.00	.00	188	164	865	724	202	153	155	643	--
14	.00	.00	.00	179	209	858	595	493	153	156	691	--
15	.00	.00	.00	168	262	830	603	203	146	155	18	--
16	.00	.00	.00	166	285	640	409	388	142	155	--	--
17	.00	.00	.00	169	288	679	206	367	151	156	--	--
18	.00	.00	.00	186	320	695	285	154	153	155	--	--
19	.00	.00	113	155	280	693	509	155	156	155	--	--
20	.00	.00	146	159	281	666	530	496	154	281	--	--
21	.00	.00	240	183	256	515	769	225	155	218	--	--
22	.00	.00	240	200	163	507	772	154	156	206	--	--
23	.00	.00	184	211	165	514	813	154	155	217	--	--
24	.00	.00	187	176	165	573	828	154	153	296	--	--
25	.00	.00	189	164	162	541	752	155	154	328	--	--
26	.00	.00	188	157	168	485	372	155	154	303	--	--
27	.00	.00	170	144	172	501	273	154	154	294	--	--
28	.00	.00	149	182	300	582	234	154	163	268	--	--

Table 8. Summary of information and daily mean discharge for streamflow-gaging station 07122005 Fort Lyon Canal near La Junta (site S1), 1989–90--Continued

Day	Daily mean discharge (cubic feet per second)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
	January through December 1990--Continued											
29	0.00	--	176	169	808	431	270	155	162	289	--	--
30	.00	--	268	180	915	480	683	152	213	278	--	--
31	.00	--	335	--	868	--	959	140	--	482	--	--
MEAN	.00	.00	83.40	197	385	657	535	301	154	208	589	--
MAX	.00	.00	335	345	938	877	959	759	213	482	691	--
MIN	.00	.00	.00	139	162	431	167	140	133	151	18	--
AC-FT	.00	.00	5,130	11,750	23,680	39,090	32,920	18,520	9,140	12,780	17,520	--

Table 9. Summary of information and daily mean discharge for streamflow-gaging station 381024103195401 Adobe Creek near Fort Lyon Canal (site S3), 1989–90

[--, no data; MAX, maximum; MIN, minimum; AC-FT, acre-feet]

LOCATION.—Lat 38°10'31", long 103°19'54", in SW 1/4 SE 1/4 sec. 34, T. 21 S., R. 53 W., Bent County, Hydrologic Unit 11020009, on right bank about 1.5 miles northwest of McIntosh Ranch, about 7 miles downstream from Adobe Creek Reservoir, and about 3 miles north of the Fort Lyon Canal.

GAGE.—Nonrecording gage read twice daily for water stage. Reference is a staff plate attached to the right wall in the approach section of a concrete standard 20-foot Parshall flume.

COOPERATION.—Water-stage readings collected by the Fort Lyon Canal Company and records computed and reviewed by the U.S. Geological Survey.

Day	Daily mean discharge (cubic feet per second)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
	January through December 1989											
1	--	--	--	266	326	--	--	--	163	19	--	--
2	--	--	--	279	326	--	--	--	163	19	--	--
3	--	--	--	314	326	--	--	--	163	19	--	--
4	--	--	--	332	326	--	--	--	162	15	--	--
5	--	--	--	332	324	--	--	--	158	4.3	--	--
6	--	--	--	332	324	--	--	--	157	1.3	--	--
7	--	--	--	332	324	--	--	--	149	--	--	--
8	--	--	--	332	322	--	--	--	148	--	--	--
9	--	--	--	332	320	--	--	--	148	--	--	--
10	--	--	--	332	312	--	--	--	138	--	--	--
11	--	--	--	330	310	--	--	--	117	--	--	--
12	--	--	--	328	308	--	--	--	111	--	--	--
13	--	--	--	326	304	--	--	--	110	--	--	--
14	--	--	--	326	298	--	--	--	94	--	--	--
15	--	--	--	326	219	--	251	--	71	--	--	--
16	--	--	--	326	--	--	364	183	64	--	--	--
17	--	--	--	324	--	--	390	283	55	--	--	--
18	--	--	--	322	--	--	398	286	49	--	--	--
19	--	--	--	322	--	--	398	286	48	--	--	--
20	--	--	--	324	117	--	398	285	47	--	--	--
21	--	--	--	326	185	--	281	277	45	--	--	--
22	--	--	132	328	98	--	72	253	38	--	--	--
23	--	--	149	328	--	--	--	188	36	--	--	--
24	--	--	--	328	--	--	--	168	36	--	--	--
25	--	--	--	328	--	--	--	165	35	--	--	--
26	--	--	--	328	--	--	--	163	30	--	--	--
27	--	--	--	328	--	--	--	163	29	--	--	--
28	--	--	138	328	--	--	--	163	25	--	--	--
29	--	--	203	328	--	--	--	163	20	--	--	--
30	--	--	253	328	--	--	--	163	19	--	--	--

Table 9. Summary of information and daily mean discharge for streamflow-gaging station 381024103195401 Adobe Creek near Fort Lyon Canal (site S3), 1989–90--Continued

Day	Daily mean discharge (cubic feet per second)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
					January through December 1989--Continued							
31	--	--	268	--	--	--	--	163	--	--	--	--
MEAN	--	--	190	324	282	--	319	209	87.6	12.9	--	--
MAX	--	--	268	332	326	--	398	286	163	19	--	--
MIN	--	--	132	266	98	--	72	163	19	1.3	--	--
AC-FT	--	--	2,270	19,270	10,050	--	5,060	6,650	5,210	154	--	--
					January through December 1990							
1	--	--	--	--	--	--	52	.00	377	--	--	--
2	--	--	--	--	--	--	95	.00	377	--	--	--
3	--	--	--	--	--	--	155	.00	356	--	--	--
4	--	--	--	--	--	--	308	.00	277	--	--	--
5	--	--	--	--	--	--	394	.00	217	--	--	--
6	--	--	--	--	--	--	387	.00	185	--	--	--
7	--	--	--	--	--	--	273	.00	157	--	--	--
8	--	--	--	--	--	--	--	166	138	--	--	--
9	--	--	--	--	--	--	--	348	122	--	--	--
10	--	--	--	--	--	--	77	396	106	--	--	--
11	--	--	--	--	--	--	--	390	93	--	--	--
12	--	--	--	--	--	--	--	387	76	--	--	--
13	--	--	--	--	--	--	--	383	72	--	--	--
14	--	--	--	--	--	--	--	352	72	--	--	--
15	--	--	--	--	--	--	--	296	72	--	--	--
16	--	--	--	--	--	--	--	298	67	11	--	--
17	--	--	--	--	--	--	228	176	52	17	--	--
18	--	--	--	--	--	--	330	308	47	13	--	--
19	--	--	--	--	--	--	170	377	46	10	--	--
20	--	--	--	--	--	--	81	175	43	9.0	--	--
21	--	--	--	--	--	--	--	202	39	7.3	--	--
22	--	--	--	--	104	--	--	377	37	6.2	--	--
23	--	--	--	--	165	--	--	381	34	3.4	--	--
24	--	--	--	--	175	--	--	377	31	1.3	--	--
25	--	--	--	--	175	70	--	372	28	3.0	--	--
26	--	--	--	--	175	114	--	381	26	4.3	--	--
27	--	--	--	--	175	121	--	398	26	4.3	--	--
28	--	--	--	--	128	122	81	398	17	4.3	--	--

Table 9. Summary of information and daily mean discharge for streamflow-gaging station 381024103195401 Adobe Creek near Fort Lyon Canal (site S3), 1989–90--Continued

Day	Daily mean discharge (cubic feet per second)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
	January through December 1990--Continued											
29	--	--	--	--	--	122	82	398	--	4.3	--	--
30	--	--	--	--	--	86	--	387	--	3.0	--	--
31	--	--	--	--	--	--	--	377	--	--	--	--
MEAN	--	--	--	--	157	106	194	261	114	6.76	--	--
MAX	--	--	--	--	175	122	394	398	377	17	--	--
MIN	--	--	--	--	104	70	52	0.00	17	1.3	--	--
AC-FT	--	--	--	--	2,180	1,260	5,380	16,070	6,330	201	--	--

Table 10. Summary of information and daily mean discharge for streamflow-gaging station 07122385 Wheatridge Lateral near May Valley (site S7), 1989–90

[--, no data; MAX, maximum; Min, minimum; AC-FT, acre-feet]

LOCATION.—Lat 38°11'37", long 102°34'36", in center NW 1/4 SW 1/4 sec. 27, T. 21 S., R. 46 W., Prowers County, Hydrologic Unit 11020009, on left bank about 0.75 mile southwest of Kroell benchmark, about 4.5 miles from junction of highways 169 and 196, about 0.45 mile north of Road RR on west side of Road 10, and 103.7 canal miles downstream from the second diversion dam on the Fort Lyon Canal.

GAGE.—A water-stage recorder housed in a 4.5- by 4.5-foot frame shelter records water-stage height from a stilling well in hydraulic connection with a concrete standard 10-foot Parshall flume. Outside reference is a staff plate attached to the left wall in the approach section of the flume.

Day	Daily mean discharge (cubic feet per second)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
	January through December 1989											
1	0.00	0.00	0.00	80	0.00	0.96	39	0.00	102	0.00	0.00	0.00
2	.00	.00	.00	.00	.00	.77	.00	.00	91	.00	.00	.00
3	.00	.00	.00	.00	.00	.77	.00	.00	6.8	.00	.00	.00
4	.00	.00	.00	.00	24	108	.00	49	.00	.00	.00	.00
5	.00	.00	.00	.00	73	13	.00	83	.00	.00	.00	.00
6	.00	.00	.00	.00	59	3.1	.00	59	.00	.00	.00	.00
7	.00	.00	.00	49	.00	132	.00	.00	.00	.00	61	.00
8	.00	.00	.00	107	.00	191	.00	.00	.00	.00	98	.00
9	.00	.00	.00	55	.00	167	36	.00	.00	.00	68	.00
10	.00	.00	.00	.00	.00	140	88	.00	.00	.00	.00	.00
11	.00	.00	.00	.00	.00	8.1	89	54	.00	.00	.00	.00
12	.00	.00	.00	.00	.00	6.4	9.3	65	.00	.00	.00	.00
13	.00	.00	.00	.00	.00	6.1	.00	56	.00	.00	.00	.00
14	.00	.00	.00	.00	38	107	.00	.00	.00	62	.00	.00
15	.00	.00	.00	.00	77	173	.00	.00	31	93	.00	.00
16	.00	.00	.00	74	79	151	.00	.00	83	31	.00	.00
17	.00	.00	.00	95	22	36	.00	.00	85	.00	.00	.00
18	.00	.00	.00	68	.00	33	.00	33	.00	.00	21	.00
19	.00	.00	.00	.00	.00	31	23	56	.00	.00	64	.00
20	.00	.00	.00	.00	28	88	101	93	.00	.00	1.6	.00
21	.00	.00	.00	.00	43	187	93	27	.00	.00	.00	.00
22	.00	.00	.00	.00	72	161	.60	.00	.00	.00	.00	.00
23	.00	.00	.00	.00	53	2.7	.00	.00	.00	.00	.00	.00
24	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
25	.00	.00	.00	28	.00	.00	.00	.00	.00	.00	.00	.00
26	.00	.00	.00	105	.00	.00	.00	.00	.00	.00	.00	.00
27	.00	.00	.00	82	.00	.00	57	.00	.00	.00	.00	.00
28	.00	.00	45	.00	.00	31	77	.00	.00	.00	.00	.00
29	.00	--	78	.00	55	55	60	.00	.00	.00	.00	.00
30	.00	--	84	.00	75	57	.00	4.9	.00	.00	.00	.00

Table 10. Summary of information and daily mean discharge for streamflow-gaging station 07122385 Wheatridge Lateral near May Valley (site S7), 1989–90--Continued

Day	Daily mean discharga (cubic feet per second)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
					January through December 1989—Continued							
31	0.00	--	101	--	24	--	0.00	41	--	0.00	--	0.00
MEAN	.00	0.00	9.94	24.8	23.3	63.0	21.7	20.0	13.3	6.00	10.5	.00
MAX	.00	.00	101	107	79	191	101	93	102	93	98	.00
MIN	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
AC-FT	.00	.00	611	1,470	1,430	3,750	1,330	1,230	791	369	622	.00
					January through December 1990							
1	.00	.00	.00	.00	.00	.00	93	16	4.8	.00	.00	--
2	.00	.00	.00	.00	.00	.00	96	16	2.0	.00	.00	--
3	.00	.00	.00	.00	.00	57	35	16	.00	.00	.00	--
4	.00	.00	.00	.00	.00	96	2.3	57	.00	.00	30	--
5	.00	.00	.00	.00	.00	51	8.0	53	.00	2.2	112	--
6	.00	.00	.00	.00	.00	1.4	2.0	16	.00	47	69	--
7	.00	.00	.00	.00	.00	7.2	19	73	.00	97	.41	--
8	.00	.00	.00	.00	.00	42	6.8	90	.00	106	.19	--
9	.00	.00	.00	.00	.00	96	57	30	3.7	54	58	--
10	.00	.00	.00	.47	61	100	80	4.4	61	.95	103	--
11	.00	.00	.00	1.1	82	3.0	44	4.0	109	.00	52	--
12	.00	.00	.00	3.7	86	.71	4.2	3.8	70	.00	12	--
13	.00	.00	.00	2.1	29	5.3	4.3	67	3.7	.00	50	--
14	.00	.00	.00	7.6	.00	.00	4.2	98	.00	.00	92	--
15	.00	.00	.00	9.6	.00	7.8	57	67	.00	.00	70	--
16	.00	.00	.00	12	.00	48	90	24	.00	.00	18	--
17	.00	.00	.00	5.0	.00	61	90	23	.00	.00	2.8	--
18	.00	.00	.00	65	.00	84	16	26	.00	.00	2.8	--
19	.00	.00	.00	79	.00	91	7.3	26	.00	.00	2.7	--
20	.00	.00	.00	83	.00	9.9	6.8	26	.00	.00	2.3	--
21	.00	.00	.00	26	.00	41	37	55	.00	.00	1.9	--
22	.00	.00	.00	.00	.00	74	101	89	.00	.00	1.9	--
23	.00	.00	.00	.00	.00	21	84	75	.00	.00	2.0	--
24	.00	.00	.00	.00	60	1.5	17	11	.00	.00	2.1	--
25	.00	.00	.00	.00	95	.47	11	9.4	.00	.00	2.1	--
26	.00	.00	.00	.00	81	4.4	11	9.0	.00	31	2.1	--
27	.00	.00	.00	.00	7.9	.84	11	9.2	.00	101	2.1	--

Table 10. Summary of information and daily mean discharge for streamflow-gaging station 07122385 Wheatridge Lateral near May Valley (site S7), 1989–90--Continued

Day	Daily mean discharge (cubic feet per second)											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
	January through December 1990--Continued											
28	0.00	0.00	0.00	0.00	0.00	4.5	11	9.0	0.00	84	--	--
29	.00	--	.00	.00	.00	8.6	41	26	.00	--	--	--
30	.00	--	.00	.00	.00	80	93	102	.00	.00	--	--
31	.00	--	.00	--	.00	--	83	76	--	.00	--	--
MEAN	.00	.00	.00	9.82	16.2	33.3	39.4	38.9	8.47	17.4	25.6	--
MAX	.00	.00	.00	83	95	100	101	102	109	106	112	--
MIN	.00	.00	.00	.00	.00	.00	2.0	3.8	.00	.00	.00	--
AC-FT	.00	.00	.00	584	996	1,980	2,430	2,390	504	1,040	1,370	--

Table 11. Summary of irrigated acreage, crop acreage, and other acreage of the Fort Lyon Canal, by canal division, 1989–90

[Source: U.S. Agricultural Stabilization and Conservation Service (written commun., 1989, 1990)]

Division	Irrigated acreage (acres)	Crop acreage (acres)							Other acreage (acres)	
		Alfalfa	Spring grains		Corn	Sorghum	Wheat	Pasture	Fallow land	Unknown crop use
			Oats	Barley						
					1989					
La Junta	2,160	660	4	0	426	310	136	380	92	152
Horse Creek	9,460	3,714	95	11	1,672	1,334	641	763	1,053	177
Las Animas	13,840	5,810	76	0	3,007	2,065	681	324	1,595	282
Limestone	29,420	17,781	180	276	1,457	5,287	2,166	315	1,757	201
Lamar	36,700	26,589	207	237	1,986	3,690	2,424	179	1,365	23
Total	91,580	54,554	562	524	8,548	12,686	6,048	1,961	5,862	835
					1990					
La Junta	2,140	990	0	0	499	150	37	208	131	125
Horse Creek	9,290	4,268	45	4	1,117	1,474	482	725	953	222
Las Animas	13,960	6,221	42	0	2,921	1,756	624	432	1,614	350
Limestone	29,900	18,929	293	60	1,523	4,872	2,076	505	1,280	362
Lamar	36,380	27,372	21	44	1,896	3,120	2,479	197	1,245	6
Total	91,670	57,780	401	108	7,956	11,372	5,698	2,067	5,223	1,065

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