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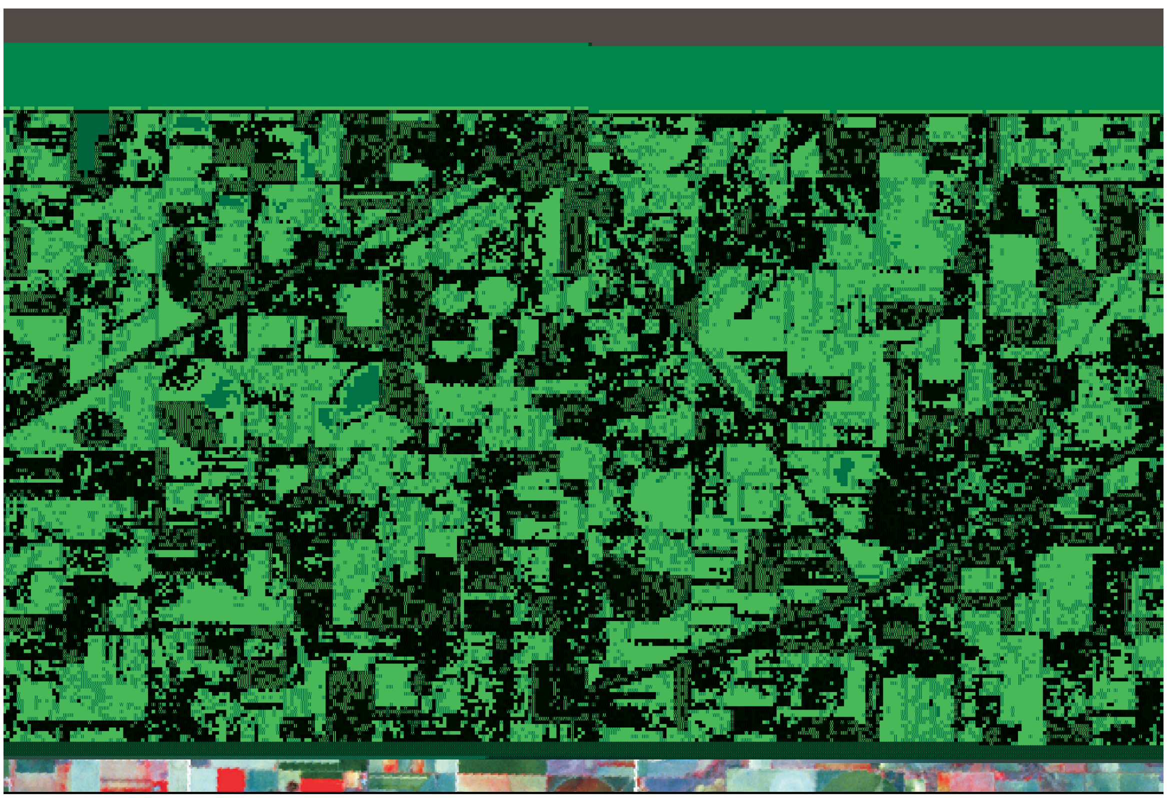
Comparison of Irrigation Water Use Estimates Calculated From Remotely Sensed Irrigated Acres and State Reported Irrigated Acres in the Lake Altus Drainage Basin, Oklahoma and Texas, 2000 Growing Season

Water-Resources Investigations Report 03-4155



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By Jason R. Masoner[1], Carol S. Mladinich[2], Alexandria M. Konduris[2], and S. Jerrod Smith[1]

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Conversion Factors and Datum

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.004047	square kilometer (km^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	0.003785	cubic meter (m^3)
acre-foot (acre-ft)	43,560	cubic feet (ft^3)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Flow rate	
cubic foot (ft^3)	7.48	gallon (gal)
million gallons per day (Mgal/d)	0.003785	cubic meter per day (m^3/d)
	Watts	
langleys per day (lang/day)	1,004,140.8	watts per meter squared (watts/m^2)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C = (°F - 32) / 1.8$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is North American Datum of 1983 (NAD 83).

Comparison of Irrigation Water Use Estimates Calculated From Remotely Sensed Irrigated Acres and State Reported Irrigated Acres in the Lake Altus Drainage Basin, Oklahoma and Texas, 2000 Growing Season

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Abstract

Increased demand for water in the Lake Altus drainage basin requires more accurate estimates of water use for irrigation. The U.S. Geological Survey, in cooperation with the U.S. Bureau of Reclamation, is investigating new techniques to improve water-use estimates for irrigation purposes in the Lake Altus drainage basin. Empirical estimates of reference evapotranspiration, crop evapotranspiration, and crop irrigation water requirements for nine major crops were calculated from September 1999 to October 2000 using a solar radiation-based evapotranspiration model. Estimates of irrigation water use were calculated using remotely sensed irrigated crop acres derived from Landsat 7 Enhanced Thematic Mapper Plus imagery and were compared with irrigation water-use estimates calculated from irrigated crop acres reported by the Oklahoma Water Resources Board and the Texas Water Development Board for the 2000 growing season. The techniques presented will help manage water resources in the Lake Altus drainage basin and may be transferable to other areas with similar water management needs.

Irrigation water use calculated from the remotely sensed irrigated acres was estimated at 154,920 acre-feet; whereas, irrigation water use calculated from state reported irrigated crop acres was 196,026 acre-feet, a 23 percent difference. The greatest difference in irrigation water use was in Carson County, Texas. Irrigation water use for Carson County, Texas, calculated from the remotely sensed irrigated acres was 58,555 acre-feet; whereas, irrigation water use calculated from state reported irrigated acres was 138,180 acre-feet, an 81 percent difference. The second greatest difference in irrigation water use occurred in Beckham County, Oklahoma. Differences between the two irrigation water use estimates are due to the differences of irrigated crop acres derived from the mapping process and those reported by the Oklahoma Water Resources Board and Texas Water Development Board.

Introduction

Increased demand for water in the Lake Altus drainage basin requires more accurate estimates of water use for irrigation. Agriculture is the primary land use in the drainage basin. Ninety-one percent of water use in the drainage basin in 1995 was for irrigation purposes (R.L. Tortorelli, USGS, written commun., 2001). Lake Altus supplies water to the Lugert-Altus Irrigation District using a 270-mile system of canals downstream from the dam (Oklahoma Water Resources Board, 2000). Lake Altus was built by the Bureau of Reclamation from 1941 to 1948 for flood control, water supply for the City of Altus, and irrigation of about 46,000 acres (A. Ensley, Lugert-Altus Irrigation District, oral commun., 2002). The Lugert-Altus Irrigation District annually supplies more than 85,000 acre-feet of water for agricultural purposes (Oklahoma Water Resources Board, 2000).

The U.S. Geological Survey, in cooperation with the U.S. Bureau of Reclamation, investigated new techniques to improve water-use estimates for irrigation purposes in the Lake Altus drainage basin (fig. 1). Empirical estimates of reference evapotranspiration, crop evapotranspiration, and crop irrigation water requirements for alfalfa, corn, cotton, hay, peanuts, sorghum, soybeans, sunflowers, and wheat were calculated on a monthly and seasonal basis from September 1999 to October 2000 using an evapotranspiration model by Doorenbos and Pruitt (1977). The model is commonly referred to as the radiation method and is accurate in arid and sub-humid areas and less accurate near the ocean in cooler climates (U.S. Department of Agriculture, 1993). These empirical estimates of irrigation water use were used with estimated irrigated acres to calculate irrigation water use in the Lake Altus drainage basin in Oklahoma and Texas.

Purpose and Scope

The purpose of this report is to present the techniques and results of an effort to map irrigated crop acres in the Lake Altus drainage basin using satellite imagery and remote sensing tech-

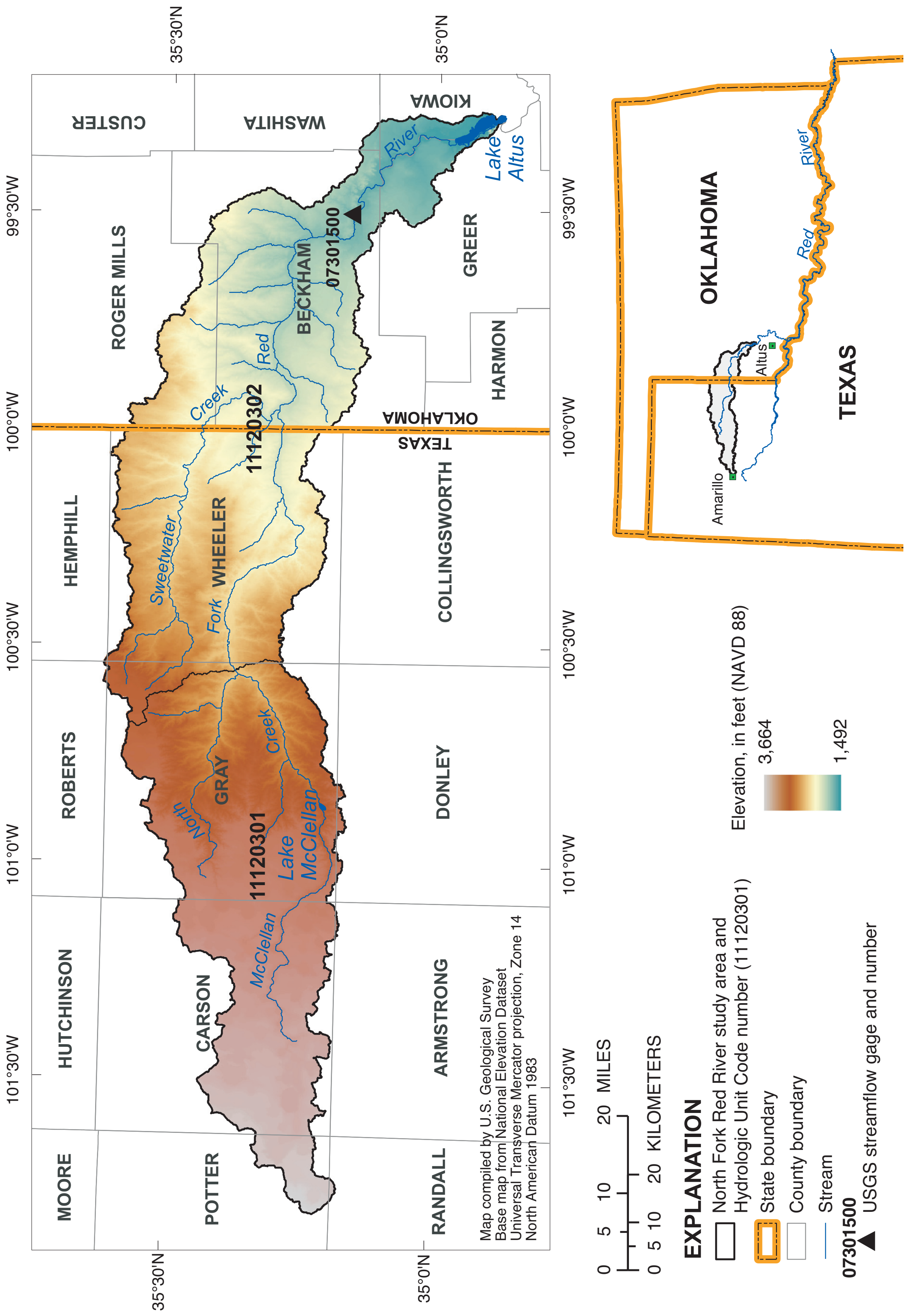

Figure 1. Map of the Lake Altus drainage basin.

niques, and compare irrigation water use estimates calculated from the remotely sensed irrigated acres with those calculated from state reported irrigated crop acres for the 2000 growing season. This report presents: (1) mapping of land use and irrigated crop acres from multiple dates of Landsat 7 Enhanced Thematic Mapper Plus (ETM+) imagery; (2) reported irrigated crop acres from Oklahoma Water Resources Board (OWRB) and Texas Water Development Board (TWDB); (3) seasonal estimates of reference evapotranspiration, crop evapotranspiration, and crop irrigation water requirements; (4) seasonal estimates of irrigation water use for alfalfa, corn, cotton, hay, peanuts, sorghum, soybeans, sunflowers, and wheat; and (5) a comparison of irrigation water use estimates calculated from remotely sensed irrigated acres and irrigation water use estimates calculated from the state reported irrigated acres.

Seasonal irrigation water use, referred to in this report as irrigation water use during the 2000 growing season, was calculated for each crop on a countywide basis for major crops by multiplying seasonal irrigation requirements by the number of irrigated crop acres in each county. Irrigation water use was calculated using two sources of irrigated crop acres: (1) irrigated crop acres derived from remote sensing techniques and Landsat 7 ETM+ imagery, referred to as remotely sensed irrigated acres; and (2) irrigated acres reported by the OWRB and the TWDB, referred to as state reported irrigated acres. Irrigation water use estimates calculated from remotely sensed irrigated crop acres were compared with irrigation water use estimates calculated from state reported irrigated acres for the 2000 growing season.

Estimates of water use for irrigation provided in this report will facilitate better management of water resources in the Lake Altus drainage basin. Methodologies described in this report to calculate estimates of reference evapotranspiration, crop evapotranspiration, crop irrigation water requirements, and irrigation water use, may be transferable to other areas that may have similar water management needs. The irrigation water requirements presented in this report can be used with estimates of irrigated acres from anywhere in the drainage basin to calculate irrigation water use.

Description of Study Area

The study area consists of the Lake Altus drainage basin (fig.1). Lake Altus is located on the border of Greer and Kiowa Counties in southwestern Oklahoma, approximately 20 miles north of the town of Altus. The drainage area for Lake Altus is approximately 2,515 square miles, 399 square miles of which are non-contributing (Blazs and others, 2001). Most of the drainage basin, includes parts of Beckham, Carson, Gray, and Wheeler Counties (table 1).

The North Fork Red River is the major source of surface-water inflow for Lake Altus. The North Fork Red River is one of five major tributaries of the Red River. U.S. Geological Survey streamflow-monitoring station 07301500, North Fork Red River Near Carter, Oklahoma, recorded a mean annual flow of 93,230 acre-feet from 1945 through 2000 (Blazs and others, 2001). Average annual precipitation in the study area ranges from about 18 inches in the west at the headwaters to 26 inches near Lake Altus in the east (Daly and others, 1994).

Agriculture is the major land use and is mainly supported by water from the High Plains Aquifer, also referred to as the Ogallala Aquifer, and alluvial and terrace deposits along the North Fork Red River.

The High Plains Aquifer is an unconsolidated and semi-consolidated aquifer of Tertiary age and associated alluvial and terrace deposits are of Quaternary age (Havens and others, 1985, p. 348). The High Plains Aquifer consists mostly of fine sand and silts with lesser quantities of clay, gravel, and minor beds of limestone and caliche (Hart and others, 1976). Well yields range from 100 to 1,000 gallons per minute; with some yields exceeding 1,500 gallons per minute (Havens and others, 1985, p. 347).

The North Fork Red River alluvial and Beckham and Tillman terrace deposits consist of silt, clay, and gravel grading downward into fine to coarse sand (Havens and others, 1985, p. 348). Well yields range from 100 – 200 gallons per minute in the alluvium and 200 – 500 gallons per minute in the Beckham and Tillman terrace (Havens and others, 1985, p. 348).

The length of growing season for crops is closely related to temperature and has a substantial effect on the amount of water used by crops. There are two primary growing seasons in the Lake Altus drainage basin. Winter wheat is grown in the first growing season, which occurs from early October through early May (peak greenness), with harvesting in early June (McDaniels, 1960, and U.S. Department of Agriculture, 1998). Corn, cotton, peanuts, sorghum, soybeans, and sunflowers are grown in the second growing season, which occurs from mid-March through late July to mid-August (peak greenness) with harvesting in September or November (McDaniels, 1960, and U.S. Department of Agriculture, 1998).

Previous Study

Heimes and Luckey (1982) describe a method for estimating historical irrigation water requirements for the High Plains Aquifer from 1949 though 1978. There were two primary components used to estimate irrigation water use; irrigated crop acres and crop irrigation requirements. The report by Heimes and Luckey (1982) acquired estimates of irrigated acres by county from the Census of Agriculture (U.S. Department of Commerce, 1949 to 1978). A modified version of the Blaney-Criddle formula was used to estimate irrigation water requirements for major crops growing above the High Plains Aquifer (U.S. Department of Agriculture, 1970). The Modified Blaney-Criddle differs from the original Blaney-Criddle in that two adjustment factors are used to better estimate crop evapotranspiration. A climate coefficient correlates monthly crop evapotranspiration with the mean monthly temperature, and a growth-stage coefficient tracks crop growth development throughout the growing cycle. The Modified Blaney-Criddle method is

Table 1. Portions of counties in Oklahoma and Texas in the Lake Altus drainage basin

Counties	State	Portion of county in drainage basin (acres)	Portion of county in drainage basin (percent)
Beckham	Okla.	365,310	20.4
Greer	Okla.	47,686	2.7
Kiowa	Okla.	32,384	1.8
Roger Mills	Okla.	94,737	5.2
Washita	Okla.	2,551	0.1
Carson	Tex.	264,860	14.7
Donley	Tex.	7,101	0.4
Gray	Tex.	471,616	26.3
Randall	Tex.	1,227	0.1
Potter	Tex.	40,104	2.2
Wheeler	Tex.	467,473	26.1

widely used because of the limited climate information needed to calculate crop evapotranspiration and has been widely used historically by federal and state agriculture programs. There are more accurate methods that use solar radiation, wind speed, temperature, and humidity data to estimate crop evapotranspiration (U.S. Department of Agriculture, 1970).

Historical Freshwater Withdrawals

Freshwater withdrawal estimates for 1995 were obtained for 8-digit Hydrologic Unit Code (HUC) 11120301 and 11120302 (fig. 1) from the U.S. Geological Survey (R.L. Tortorelli, USGS, written commun., 2001). Total consumptive use from the Lake Altus drainage basin was estimated to be 120,983 acre-feet or 108.15 million gallons per day. Consumptive use for irrigation was estimated to be 109,781 acre-feet or 98.24 million gallons per day (table 2). Ground water supplies about 69 percent of total self-supplied water withdraws in the drainage basin; whereas, surface water accounts for the remaining 31 percent. The western half (11120301) of the study area accounted for 61 percent of the total self-supplied withdrawals in the drainage basin because of greater withdrawals from the High Plains Aquifer for irrigation. Withdrawals in the western half (11120301) are predominantly supplied by ground water (94 percent); whereas, withdrawals in the eastern half (11120302) are predominantly supplied by surface water (72 percent) (table 2).

Irrigation accounts for 82 percent of total self-supplied water withdrawals in the drainage basin. However, the majority of surface-water withdrawals and irrigated acres in the eastern half are utilized downstream in the Altus-Lugert Irrigation District. The distribution of other less prevalent self-supplied withdrawals included 4.9 percent for public use, 4.5 percent for livestock use, 4.4 percent for industrial use, 3.6 percent for mining use, and 0.4 percent for domestic use (calculated from table 2). Detailed explanations of water use terms used in this section can be acquired at URL http://ok.water.usgs.gov/wateruse/definitions.html

Acknowledgments

The authors wish to express their appreciation to personnel from U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS) and Farm Service Agency (FSA) offices for providing field maps of croplands and information about agricultural practices that were used to calibrate remote sensing data when determining irrigated croplands. Howard Johnson, Oklahoma Climatological Survey (OCS) and Cleon Napkin, NRCS, provided climate data used in this report. Jerry Walker and Tom Spofford, NRCS, provided technical advice about the evapotranspiration model used for this report. Michael Sughru, U.S. Geological Survey made several suggestions to improve the remote sensing part of this report.

Table 2. 1995 estimated freshwater withdrawals for cataloging units 11120301 and 11120302 (data source, R.L. Tortorelli, U.S. Geological Survey, written commun., 2001)

[data units in million gallons per day (mgd) unless noted; gal/day, gallon per day]

Public supply category	1120301	1120302	Total basin	Commercial category	1120301	1120302	Total basin
Population served by ground water, in thousands	7.64	20.21	27.85	Total self-supplied withdrawals, ground water	0.07	0.25	0.32
Population served by surface water, in thousands	4.64	0.00	4.64	Total self-supplied withdrawals, surface water	0.00	0.00	0.00
Total population served, in thousands	12.28	20.21	32.49	Total self-supplied withdrawals	0.07	0.25	0.32
Total self-supplied withdrawals, ground water	1.25	4.74	5.99	Consumptive use, total	0.04	0.10	0.14
Total self-supplied withdrawals, surface water	0.00	0.00	0.00				
Total self-supplied withdrawals, total	1.25	4.74	5.99				
Per-capita use, in gal/d	101.79	234.53	184.36				
Domestic category	**1120301**	**1120302**	**Total basin**	**Industrial category**	**1120301**	**1120302**	**Total basin**
Self-supplied population, in thousands	1.20	1.85	3.05	Total self-supplied withdrawals, ground water	5.19	0.20	5.39
Total self-supplied withdrawals, ground water	0.26	0.21	0.47	Total self-supplied withdrawals, surface water	0.00	0.00	0.00
Total self-supplied withdrawals, surface water	0.00	0.00	0.00	Total self-supplied withdrawals	5.19	0.20	5.39
Total self-supplied withdrawals	0.26	0.21	0.47	Consumptive use, total	0.34	0.04	0.38
Per-capita use, self-supplied, in gal/d	216.67	113.51	154.10				
Per-capita use, public-supplied, in gal/d	194.63	95.99	133.27				
Consumptive use, total	1.06	0.73	1.79				
Mining category	**1120301**	**1120302**	**Total basin**	**Total livestock category**	**1120301**	**1120302**	**Total basin**
Total self-supplied withdrawals, ground water	3.65	0.73	4.38	Total self-supplied withdrawals, ground water	0.66	0.63	1.29
Total self-supplied withdrawals, surface water	0.00	0.00	0.00	Total self-supplied withdrawals, surface water	1.84	2.25	4.09

Table 2. 1995 estimated freshwater withdrawals for cataloging units 11120301 and 11120302 (data source, R.L. Tortorelli, U.S. Geological Survey, written commun., 2001)—Continued.

[data units in million gallons per day (mgd) unless noted; gal/day, gallon per day]

Mining category—Continued	1120301	1120302	Total basin
Total self-supplied withdrawals	3.65	0.73	4.38
Consumptive use, total	2.12	0.10	2.22

Total livestock category—Continued	1120301	1120302	Total basin
Total self-supplied withdrawals	2.50	2.88	5.38
Consumptive use, total	2.50	2.88	5.38

Irrigation category	1120301	1120302	Total basin
Total self-supplied withdrawals, ground water	59.09	6.80	65.89
Total self-supplied withdrawals, surface water	2.41	31.80	34.21
Total self-supplied withdrawals	61.50	38.60	100.10
Consumptive use, total	61.50	36.74	98.24
Conveyance loss	0.00	1.59	1.59
Thousand acres irrigated, sprinkler	22.10	11.35	33.45
Thousand acres irrigated, microirrigation	0.01	0.13	0.14
Thousand acres irrigated, surface water	38.06	38.73	76.79
Thousand acres irrigated	60.17	50.21	110.38
Reclaimed wastewater	2.69	0.08	2.77

Reservoir evaporation category	1120301	1120302	Total basin
Reservoir surface area, in thousand acres	0.32	4.74	5.06
Reservoir evaporation, in thousand acre-feet per year	1.59	23.16	24.75

Totals, overall category	1120301	1120302	Total basin
Total self-supplied withdrawals, ground water	70.17	13.56	83.73
Total self-supplied withdrawals, surface-water	4.25	34.05	38.30
Total self-supplied withdrawals	74.42	47.61	122.03
Total consumptive use	67.56	40.59	108.15
Total conveyance losses	0.00	1.59	1.59