

Method for Estimating Water Withdrawals for Livestock in the United States, 2005



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U.S. Department of the Interior
U.S. Geological Survey



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Conversion Factors

Multiply	By	To obtain
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m ³)
million gallons (Mgal)	3,785	cubic meter (m ³)
gallon per day (gal/d)	0.003785	cubic meter per day (m ³ /d)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m ³ /s)
square mile (mi ²)	2.590	square kilometer (km ²)

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Abstract

Livestock water use includes ground water and surface water associated with livestock watering, feedlots, dairy operations, and other on-farm needs. The water may be used for drinking, cooling, sanitation, waste disposal, and other needs related to the animals. Estimates of water withdrawals for livestock are needed for water planning and management.

This report documents a method used to estimate withdrawals of fresh ground water and surface water for livestock in 2005 for each county and county equivalent in the United States, Puerto Rico, and the U.S. Virgin Islands. Categories of livestock included dairy cattle, beef and other cattle, hogs and pigs, laying hens, broilers and other chickens, turkeys, sheep and lambs, all goats, and horses (including ponies, mules, burros, and donkeys). Use of the method described in this report could result in more consistent water-withdrawal estimates for livestock that can be used by water managers and planners to determine water needs and trends across the United States.

Water withdrawals for livestock in 2005 were estimated by using water-use coefficients, in gallons per head per day for each animal type, and livestock-population data. Coefficients for various livestock for most States were obtained from U.S. Geological Survey water-use program personnel or U.S. Geological Survey water-use publications. When no coefficient was available for an animal type in a State, the median value of reported coefficients for that animal was used. Livestock-population data were provided by the National Agricultural Statistics Service. County estimates were further divided into ground-water and surface-water withdrawals for each county and county equivalent. County totals from 2005 were compared to county totals from 1995 and 2000. Large deviations from 1995 or 2000 livestock withdrawal estimates were investigated and generally were due to comparison with reported withdrawals, differences in estimation techniques, differences in livestock coefficients, or use of livestock-population data from different sources.

The results of this study were distributed to U.S. Geological Survey water-use program personnel in each State during 2007. Water-use program personnel are required to submit estimated withdrawals for all categories of use in their States to the National Water-Use Information Program for inclusion in a national report describing water use in the United States

during 2005. Water-use program personnel had the option of submitting these estimates, a modified version of these estimates, or their own set of estimates or reported data. Estimated withdrawals resulting from the method described in this report are not presented herein to avoid potential inconsistencies with estimated withdrawals for livestock that will be presented in the national report, as different methods used by water-use personnel may result in different withdrawal estimates. Estimated withdrawals also are not presented to avoid potential disclosure of data for individual livestock operations.

Introduction

Livestock water use includes ground water and surface water associated with livestock watering, feedlots, dairy operations, and other on-farm needs. The water may be used for drinking, cooling, sanitation, waste disposal, and other needs related to the animals. Livestock include cattle, swine, poultry, sheep, goats, horses, and other animals raised for commercial purposes (Hutson and others, 2004, p. 23). Fish and other aquatic animals are not included in the livestock water-use category.

The U.S. Geological Survey (USGS) has estimated water withdrawals for livestock in the United States along with withdrawals for other categories of use every 5 years since 1950. In 1950 and 1955, water withdrawals for livestock were combined with rural domestic withdrawals and included in the rural use category. From 1960 to 1980, the rural use category included separate tabulations of withdrawals for livestock and withdrawals for rural domestic use (MacKichan and Kammerer, 1961; Murray, 1968; Murray and Reeves, 1972, 1977; Solley and others, 1983). In 1985, livestock became a separate category and included withdrawals for livestock and fish farms (Solley and others, 1988). In 1990 and 1995, the livestock category included separate tabulations of withdrawals for livestock and withdrawals for animal specialties, which included among other things, horses and fish farms. In 2000, the livestock category included livestock and the animals that had formerly been included in the animal specialties category, with the exception of fish farms, which were included under a new aquaculture category (Solley and others, 1993, 1998; Hutson and others, 2004). Estimated withdrawals for livestock

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also are often published in reports of water-use estimates for individual States. Livestock withdrawals typically are less than one percent of total national water use (Hutson and others, 2004, p. 23) and are relatively minor in most States when compared to withdrawals for other categories of use, such as public supply, irrigation, industry, and power generation.

Estimates of water withdrawals for various categories of use are needed for water planning and management. Water-use data also are needed to evaluate the effects of human activity on the quantity and quality of the Nation's water resources. Large livestock operations may maintain water-use records and report this usage to a regulatory agency in some States; however, much of the livestock water use in the United States is not reported. Where water withdrawals for livestock are small or unknown, they are usually estimated by using a gallons-per-head water-use coefficient and livestock population estimates rather than actual measurements of withdrawals. Livestock population estimates are usually available from sources such as State agricultural agencies and the U.S. Department of Agriculture, National Agricultural Statistics Service (NASS). Water-use coefficients for livestock are often available from County Extension Service agents, local livestock experts, and various livestock management publications. Coefficients often vary from State to State depending on livestock management practices, water availability, climatic conditions, and local knowledge of how these factors affect water needs.

Purpose and Scope

This report documents a method used to estimate withdrawals of fresh ground water and surface water for livestock in 2005 for each county and county equivalent in the United States, Puerto Rico, and the U.S. Virgin Islands by using estimated water-use coefficients and livestock-population data. Categories of livestock included dairy cattle, beef and other cattle, hogs and pigs, laying hens, broilers and other chickens, turkeys, sheep and lambs, all goats, and horses (including ponies, mules, burros, and donkeys). A table presents the range of coefficients used for various livestock. Use of the method described in this report could result in more consistent water-withdrawal estimates for livestock that can be used by water managers and planners to determine water needs and trends across the United States.

Estimates of water withdrawals for livestock during 2005 in each county and county equivalent in the United States, Puerto Rico, and the U.S. Virgin Islands were prepared using the method described herein as an alternative to USGS water-use program personnel in each State preparing estimates for their State. County estimates were further divided into ground-water and surface-water withdrawals for each county and county equivalent. The estimates were distributed to USGS personnel in each State during 2007. Water-use program personnel are required to submit estimated withdrawals for all categories of use in their State to the

National Water-Use Information Program for inclusion in a national report describing water use in the United States during 2005. Water-use program personnel had the option of submitting these estimates, a modified version of these estimates, or their own set of estimates or reported data. Estimated withdrawals resulting from the method described in this report are not presented herein to avoid potential inconsistencies with estimated withdrawals for livestock that will be presented in the national report, as different methods used by water-use personnel may result in different withdrawal estimates. Estimated withdrawals also are not presented to avoid potential disclosure of data for individual livestock operations.

Acknowledgments

The author gratefully acknowledges the assistance and cooperation of U.S. Geological Survey hydrologists in each State who provided livestock coefficients and other pertinent water-use data for their State. Thanks also to William Alley, Deborah Lumia, Susan Hutson, Kristin Linsey, Joan Kenny, Molly Maupin, and Nancy Barber of the USGS for their guidance and input. A special thanks is given to Robert Hood, Nathan Crisp, and Patrick Clinton, National Agricultural Statistics Service, for providing access to and assistance with livestock population records.

Water Requirements for Livestock

Water is withdrawn and used at livestock operations to meet drinking and nondrinking requirements. Drinking-water requirements for livestock are attained through water available from the environment (streams, ponds, and other water bodies), water in feed, and water supplied by the farmer or rancher. Drinking-water requirements are dependent on species, size, age, and, for dairy cows especially, whether the animals are lactating or nonlactating (National Research Council, 1981, p. 41; Lardy and Stoltenow, 1999). Climate and moisture content of feed, both of which can vary seasonally, also directly affect drinking water requirements (Irwin, 1986; Natural Resources Conservation Service, 2003, p. 6-12). Typical drinking water requirements for livestock can be found in Soil Conservation Service (1975); Esmay (1977); Irwin (1986); MidWest Plan Service (1987); Wells (1995); Lardy and Stoltenow (1999); Landefeld and Bettinger (2002); Maryland Cooperative Extension Service (2002); Smith (2002); Kansas Department of Agriculture (2003); Wilson and others (2003); and Alberta Department of Agriculture, Food, and Rural Development (2005).

Nondrinking requirements include water for waste disposal, sanitation, cooling, and other needs related to animal husbandry. Water needs for waste disposal are highly variable as there are nearly as many different waste disposal systems as there are livestock operations (Soil Conservation

Service, 1975; Van Horn and others, 1993). Waste disposal can require very little water if manure is scraped but can require large amounts of water if manure is flushed. When manure is flushed, however, most of the water used is usually recycled from sewage lagoons (Falk, 2004). Waste in livestock sewage lagoons must be periodically diluted, often with ground water or surface water, to ensure proper waste decomposition and to minimize odors (Jones and Sutton, 1999). Dairy operations require water for cleaning cow udders prior to milking, sanitation of the equipment and the milking parlor, cooling of storage tanks, and other needs (Van Horn and others, 1993; Falk, 2004). Automatic udder washers reportedly use large amounts of water, but manual washing uses much less (Soil Conservation Service, 1975, p. 11; Wilson and others, 2003, p. 50). Typical nondrinking water requirements for livestock can be found in Soil Conservation Service (1975, 1992); MidWest Plan Service (1987); Van Horn and others (1993); Maryland Cooperative Extension Service (2002); Wilson and others (2003); and Alberta Department of Agriculture, Food, and Rural Development (2005).

Several agricultural researchers have developed formulas to estimate water requirements for various livestock based on animal attributes, environmental factors, and livestock management practices (Lardy and Stoltenow, 1999; Smith, 2002; Falk, 2004; Swistock and Sharpe, 2005). However, estimation and verification of water requirements based on such formulas were beyond the scope of this study.

Method for Estimating Water Withdrawals for Livestock

Water withdrawals for livestock in 2005 were estimated by using water-use coefficients, in gallons per head per day for each animal type, and livestock-population data. Withdrawals by water source, surface water or ground water, were estimated for each county or county equivalent in the United States.

Water-Use Coefficients

Water-use coefficients for livestock are average rates of water, in gallons per head per day, that are used for a type of animal in a livestock operation. These rates are based on drinking-water requirements and nondrinking-water requirements. Categories of livestock for which water use is commonly estimated include dairy cattle, beef and other cattle, swine, laying hens, broilers and other chickens, turkeys, sheep, goats, and horses. In some States, water use is estimated for other livestock categories, such as bison, elk, deer, reindeer, emus, ostriches, minks, and rabbits. Estimates of water used for these other livestock categories were not included in this report, however, because they generally have not been estimated in most States, and their populations (and presumably their water use) are relatively small compared to the more common livestock categories.

Water-use coefficients for various livestock for most States were obtained from USGS scientists or USGS water-use publications. Water-use coefficients for livestock used by the USGS scientists generally have been developed based on published livestock water requirements and discussions with livestock experts from State agricultural agencies and extension services. In a few States, the coefficients are based on permitted or reported withdrawal or discharge rates for livestock operations.

For this study, in cases where no coefficient was available for an animal type in a State, the median value of coefficients reported by USGS hydrologists for that animal type was used. If a livestock coefficient for a State was much higher or lower than the coefficients used by most other States, the origin of the coefficient was researched. If no plausible reference was available for a very high or very low value, the coefficient was increased or decreased as needed to fall within the range of coefficients used in most other States. The range of coefficients for each animal type is presented in table 1. In order to avoid the potential disclosure of data for individual livestock operations, livestock coefficients for individual States are not included.

Table 1. Water-use coefficients for livestock.

[Amounts are in gallons per animal per day]

Animal type	Water-use coefficients				
	Minimum	25th percentile	Median	75th percentile	Maximum
Dairy cows	18	20	35	35	65
Beef and other cattle, including calves	6.6	10	12	12	16
Hogs and pigs	2.0	2.6	3.5	4.5	8.1
Laying hens	.03	.05	.06	.09	.12
Broilers and other chickens	.02	.04	.06	.07	.10
Turkeys	.05	.08	.10	.12	.22
Sheep and lambs	.7	1.5	2.0	2.0	3.3
Goats	1.0	2.0	2.0	2.0	4.0
Horses (including ponies, mules, burros, and donkeys)	8.5	12	12	12	15

Livestock-Population Data

For the purposes of this study, a single, complete source of livestock-population data for each county or county equivalent was desirable. The NASS conducts a census of agriculture in the United States every 5 years. The census includes an inventory of livestock at each operation on a selected day, which was December 31, 2002 for the most recent census available at the time of this study (National Agricultural Statistics Service, 2005). The inventory included populations of dairy cattle, beef and other cattle, hogs and pigs, laying hens, broilers and other chickens, turkeys, sheep and lambs, all goats, and horses (including ponies, mules, burros, and donkeys) for all U.S. counties, Alaskan agricultural census areas, and Puerto Rican municipios. Livestock populations for the U.S. Virgin Islands were obtained from the 2002 NASS Census of Agriculture report for that area (National Agricultural Statistics Service, 2005). Because NASS reported combined livestock populations for the U.S. Virgin Islands of St. John and St. Thomas, half of the population for each animal type was attributed to each island. The livestock populations reported for the 2002 inventory were assumed to be representative of the average number of animals in the United States during 2005.

Estimating Water Withdrawals

Ground-water, surface-water, and total withdrawals for livestock in each county or county equivalent were estimated by using livestock-population data and State-specific water-use coefficients. Total withdrawals for livestock in each county were estimated by using the following equation:

$$Wt = ((Pdc * Cdc) + (Pbc * Cbc) + (Ph * Ch) + (Plh * Clh) + (Pbh * Cbh) + (Pt * Ct) + (Ps * Cs) + (Pg * Cg) + (Pe * Ce)) / 1,000,000 \quad (1)$$

where

- Wt* = total water withdrawals, in million gallons per day;
- Pdc* = Number of dairy cows;
- Cdc* = Coefficient for dairy cows, in gallons per day;
- Pbc* = Number of beef and other cattle;
- Cbc* = Coefficient for beef and other cattle, in gallons per day;
- Ph* = Number of hogs and pigs;
- Ch* = Coefficient for hogs and pigs, in gallons per day;
- Plh* = Number of laying hens;
- Clh* = Coefficient for laying hens, in gallons per day;
- Pbh* = Number of broilers and other chickens;
- Cbh* = Coefficient for broilers and other chickens, in gallons per day;
- Pt* = Number of turkeys;
- Ct* = Coefficient for turkeys, in gallons per day;
- Ps* = Number of sheep and lambs;
- Cs* = Coefficient for sheep and lambs, in gallons per day;

- Pg* = Number of goats;
- Cg* = Coefficient for goats, in gallons per day;
- Pe* = Number of horses, ponies, mules, burros, and donkeys; and
- Ce* = Coefficient for horses, ponies, mules, burros, and donkeys, in gallons per day.

Livestock-population data were provided by NASS. State-specific water-use coefficients generally were based on rates previously used by USGS hydrologists to estimate water withdrawals for livestock in each State. For some States, water-use coefficients were estimated or modified to more closely agree with rates used in other States and rates reported in literature. Ranges of water-use coefficients used in this study are presented in table 1.

Livestock populations for Alaska were provided by NASS agricultural census areas that comprise one or more Alaskan boroughs. Livestock withdrawals in each agricultural census area were divided into withdrawals by borough based on the percentage of agricultural census area that each borough comprises by using the following equation:

$$Wb = Wca * (Ab/Aca) \quad (2)$$

where

- Wb* = withdrawals for livestock in an Alaskan borough, in million gallons per day;
- Wca* = withdrawals for livestock in the Alaskan agricultural census area that includes the borough, in million gallons per day;
- Ab* = area of the borough, in square miles; and
- Aca* = area of the agricultural census area, in square miles.

Total withdrawals for livestock in each county or county equivalent were divided into withdrawals from ground-water and surface-water sources by using the percentage of ground-water and surface-water withdrawals for livestock in each county previously estimated by the USGS for (in order of preference) 2000, 1995, or 1990. Estimated ground-water and surface-water withdrawals for livestock in each county for 2000, 1995, and 1990 were accessed April 19, 2006 at <http://water.usgs.gov/wateruse/>.

The equations are as follows:

$$Wgw = Wt * (Wgw_x/Wt_x) \quad (3)$$

$$Wsw = Wt * (Wsw_x/Wt_x) \quad (4)$$

where

- Wgw* = ground-water withdrawals for livestock in a county, in million gallons per day;
- Wt* = total withdrawals for livestock in the county, in million gallons per day;
- Wgw_x* = (in order of preference) ground-water withdrawals for livestock in the county in 2000, 1995, or

1990, in million gallons per day;

W_{tx} = (in order of preference) total withdrawals for livestock in the county 2000, 1995, or 1990, in million gallons per day;

W_{sw} = total surface-water withdrawals for livestock in the county, in million gallons per day; and

W_{swx} = (in order of preference) surface-water withdrawals for livestock in the county in 2000, 1995, or 1990, in million gallons per day.

County totals for 2005 were compared to county totals from 1995 and 2000 (U.S. Geological Survey, 1998, 2005). Large deviations from 1995 or 2000 livestock withdrawal estimates were investigated and generally were due to comparison with reported withdrawals, differences in estimation techniques, differences in livestock coefficients, or use of livestock-population data from different sources.

Summary

Livestock water use includes ground water and surface water associated with livestock watering, feedlots, dairy operations, and other on-farm needs. The water may be used for drinking, cooling, sanitation, waste disposal, and other needs related to the animals. Livestock include cattle, swine, poultry, sheep, goats, horses, and other animals raised for commercial purposes. The U.S. Geological Survey has estimated water withdrawals for livestock in the United States, along with withdrawals for other categories of use, every 5 years since 1950. Estimates of water withdrawals for various categories of use are needed for water planning and management; however, much of the livestock water use in the United States is not reported. Where water withdrawals for livestock are small or unknown, they are usually estimated by using a gallons-per-head water-use coefficient and livestock population estimates rather than actual measurements of withdrawals. Coefficients often vary from State to State depending on livestock management practices, water availability, climatic conditions, and local knowledge of how these factors affect water needs.

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Selected References

- Alberta Department of Agriculture, Food, and Rural Development, 2005, Average daily and annual water requirements: Government of Alberta, Canada, 2 p., accessed January 19, 2006, at http://www.agric.gov.ab.ca/app19/calc/livestock/waterreq_dataentry2.jsp
- Avery, Charles, 1999, Estimated water withdrawals and use in Illinois, 1992: U.S. Geological Survey Open-File Report 99-97, 49 p.
- California State Water Resources Control Board, 1983, Appropriation of water in California: California State Water Resources Control Board, 23 p., accessed February 10, 2006, at <http://www.waterrights.ca.gov/WRINFO/> (Updated link accessed May 13, 2008, at http://weblinks.westlaw.com/Find/Default.wl?DB=CA%2DADC%2DTOC%3BRVADCCATOC&DocName=23CAADCS697&FindType=W&AP=&fn=_top&rs=WEBL8.04&vr=2.0&spa=CCR-1000&trailtype=26&Cnt=Document)

6 Method for Estimating Water Withdrawals for Livestock in the United States, 2005

- Clark, M.L., and Thamke, J.N., 1988, Estimated water use in Iowa, 1985: U.S. Geological Survey Open-File Report 87-704, 28 p.
- Esmay, Merle L., 1977, Layout and design of animal feedlot structures and equipment, in Taiganides, E. Paul, editor, 1977, Animal wastes: London, Applied Science Publishers, Ltd., 423 p.
- Falk, D.E., 2004, Fresh water needs for dairy farms: Boise, Idaho, Idaho Association of Soil Conservation Districts, 10 p., accessed March 27, 2006, at <http://www.oneplan.org/Stock/DairyWater.shtml>
- Holland, T. W., 1992, Water-use data collection techniques in the Southeastern United States, Puerto Rico, and the U.S. Virgin Islands: U.S. Geological Survey Water-Resources Investigations Report 92-4028, 187 p.
- Hutson, S.S., Barber, N.L., Kenny, J.F., Linsey, K.S., Lumia, D.S., and Maupin, M.A., 2004, Estimated use of water in the United States in 2000: U.S. Geological Survey Circular 1268, 46 p.
- Indiana Department of Natural Resources, 1982, The 1980 survey of domestic self-supplied and livestock water uses in Indiana: Indianapolis, Ind., Indiana Department of Natural Resources, Division of Water, 17 p.
- Irwin, R.W., 1977, Water requirements of livestock: Ontario Ministry of Agriculture, Food and Rural Affairs, 4 p., accessed March 27, 2006, at <http://www.omafra.gov.on.ca/english/facts/86-053.htm> (Updated link accessed May 13, 2008, at <http://www.omafra.gov.on.ca/english/engineer/facts/07-023.htm>)
- Jones, D.D., and Sutton, A.L., 1999, Design and operation of livestock waste lagoons: West Lafayette, Ind., Purdue University Cooperative Extension Service report ID-120, 18 p., accessed June 26, 2008, at <http://www.ces.purdue.edu/extmedia/ID/ID-120.html>
- Kansas Department of Agriculture, 2003, Water Appropriations Act—rules and regulations: Kansas Department of Agriculture, Division of Water Resources, 170 p., accessed January 19, 2006, at www.kansas.gov/kda/dwr/Laws-Rules/KWAARules.pdf (Updated link accessed on May 13, 2008, at http://www.ksda.gov/includes/statute_regulations/appropriation/KWAA_Rules_Regs_2006_FullVersion.pdf)
- Landefeld, Mark, and Bettinger, Jeff, 2002, Livestock water development: Columbus, Ohio, Ohio State University Extension Service Fact Sheet ANR-12-02, 3 p., accessed January 19, 2006, at <http://ohioline.osu.edu/anr-fact/0012.html>
- Lardy, Greg, and Stoltenow, Charles, 1999, Livestock and water: Fargo, N. Dak., North Dakota State University, NDSU Extension Service report AS-954, accessed January 19, 2006, at <http://www.ext.nodak.edu/extpubs/ansci/livestoc/as954w.htm>
- MacKichan, K.A., 1951, Estimated use of water in the United States, 1950: U.S. Geological Survey Circular 115, 13 p.
- MacKichan, K.A., 1957, Estimated use of water in the United States, 1955: U.S. Geological Survey Circular 398, 18 p.
- MacKichan, K.A., and Kammerer, J.C., 1961, Estimated use of water in the United States, 1960: U.S. Geological Survey Circular 456, 26 p.
- Maryland Cooperative Extension Service, 2002, Farm notes—livestock water requirements: University of Maryland, 1 p., accessed March 1, 2006, at <http://www.agnr.umd.edu/users/carrolcty/march02farmnotes.htm>
- MidWest Plan Service, 1987, Structures and environment handbook, 11th edition: Ames, Iowa, MidWest Plan Service, Iowa State University, 658 p.
- Murray, C.R., 1968, Estimated use of water in the United States, 1965: U.S. Geological Survey Circular 556, 53 p.
- Murray, C.R., and Reeves, E.B., 1972, Estimated use of water in the United States, 1970: U.S. Geological Survey Circular 676, 39 p.
- Murray, C.R., and Reeves, E.B., 1977, Estimated use of water in the United States, 1975: U.S. Geological Survey Circular 765, 37 p.
- National Agricultural Statistics Service, 2005, 2002 Census of agriculture—volume 1, geographic areas series, part 54, Virgin Islands of the United States: U.S. Department of Agriculture, 42 p., accessed April 27, 2006, at <http://www.nass.usda.gov/census/census02/usvi/usvi.pdf>
- National Research Council, 1981, Effect of environment on nutrient requirements of domestic animals: Washington, D.C., National Academies Press, National Research Council Subcommittee on Environmental Stress, 152 p., accessed April 26, 2006, at <http://www.nap.edu/books/0309031818/html/>
- Natural Resources Conservation Service, 2003, National range and pasture handbook, revision 1: U.S. Department of Agriculture, 472 p., accessed April 26, 2006, at <http://www.glti.nrcs.usda.gov/technical/publications/nrph.html>
- Shade, P. J., 1995, Estimated water use in 1990, Island of Kauai, Hawaii: U.S. Geological Survey Water-Resources Investigations Report 93-4180, 23 p.
- Smith, Bryan, 2002, Livestock water needs: Clemson, S.C., Clemson University Extension Service, 4 p., accessed March 1, 2006, at <http://www.clemson.edu/extension/drought/waterman.htm/livewat.htm>
- Soil Conservation Service, 1975, Livestock water use: U.S. Department of Agriculture, 41 p.

- Soil Conservation Service, 1992, Agricultural waste management field handbook: U.S. Department of Agriculture, Soil Conservation Service report 210-AWMFH, 695 p., accessed April 26, 2006, at <http://www.info.usda.gov/CED/ftp/CED/neh651-all.pdf>
- Solley, W.B., Chase, E.B., and Mann, W.B., IV, 1983, Estimated use of water in the United States, 1980: U.S. Geological Survey Circular 1001, 56 p.
- Solley, W.B., Merk, C.F., and Pierce, R.R., 1988, Estimated use of water in the United States in 1985: U.S. Geological Survey Circular 1004, 82 p.
- Solley, W.B., Pierce, R.R., and Perlman, H.A., 1993, Estimated use of water in the United States in 1990: U.S. Geological Survey Circular 1081, 76 p.
- Solley, W.B., Pierce, R.R., and Perlman, H.A., 1998, Estimated use of water in the United States in 1995: U.S. Geological Survey Circular 1200, 71 p.
- Steele, E.K., 1986, Estimate of livestock water use in Nebraska, 1980: U.S. Geological Survey Water-Resources Investigations Report 86-4031, 38 p.
- Swistock, B.R., and Sharpe, W.E., 2005, Water system planning—estimating water needs: Pennsylvania State University College of Agricultural Sciences Water Facts #2, 4 p., accessed April 26, 2005, at <http://pubs.cas.psu.edu/FreePubs/pdfs/XH0001.pdf>
- Templin, W.E., Hebert, R.A., Stainaker, C.B., Horn, Marilee, and Solley, W.B., 1990, Water use, chap. 11, in U.S. Geological Survey, National handbook of recommended methods for water data acquisition: U. S. Geological Survey, 135 p., accessed January 19, 2006, at <http://pubs.usgs.gov/chapter11/>
- U.S. Geological Survey, 1998, Downloading 1995 water-use data: U.S. Geological Survey, accessed August 5, 2005, at <http://water.usgs.gov/watuse/spread95/usco95.txt>
- U.S. Geological Survey, 2005, Estimated use of water in the United States—county-level data for 2000: U.S. Geological Survey, accessed August 5, 2005, at <http://water.usgs.gov/watuse/data/2000/index.html>
- Van Horn, H.H., Bray, D.R., Nordstedt, R.A., Bucklin, R.A., Bottcher, A.B., Gallaher, R.N., Chambliss, C.G., and Kidder, G., 1993, Water budgets for Florida dairy farms: Gainesville, Fla., University of Florida, Florida Cooperative Extension Service Circular 1091, 7 p., accessed March 27, 2006, at <http://edis.ifas.ufl.edu/DS121>
- Van der Leeden, Frits, Troise, F.L., and Todd, D.K., 1990, The water encyclopedia: Chelsea, Mich., Lewis Publishers, 808 p.
- Wells, Grant, 1995, Water systems for grazing livestock: Ames, Iowa, Iowa State University, University Extension PM-1604, 4 p., accessed April 26, 2005, at <http://www.extension.iastate.edu/Publications/PM1604.pdf>
- Wilson, B.C., Lucero, A.A., Romero, J.T., and Romero, P.J., 2003, Water use by categories in New Mexico counties and river basins, and irrigated acreage in 2000: New Mexico State Engineer Office, Technical Report 51, 164 p.